Attachment H

Proposal # 2001- F200 (Office Use Only)

PSP Cover Sheet (Attach to the front of each proposal)

Proposal Title: TRANSPORT, TRANSFORMATION & EFFECTS OF SE AND G IN THE DELTA: IMPLICATIONS FOR ERP

Applicant Name: ~~SAMUEL N. LUOMA, JAMES CLOERN~~
Contact Name: SAMUEL N. LUOMA, USGS
Mailing Address: MS465, 345 MIDDLEFIELD RD. MENLO PARK. CA 94025
Telephone: 650 329-4481
Fax: 650 329-4545
Email: SNLUOMA@USGS.GOV

Amount of funding requested: $3,361,160

Some entities charge different costs dependent on the source of the funds. If it is different for state or federal funds list **below.**

State cost ______ Federal *cost* ______

Cost share partners? ✓ Yes ___ No

Identify partners and amount contributed by each USGS ~ $3.5 million including collaboration with Place-Based Program. Old Dominion Univ. ~ $30,000, UC Berkeley ~ 65,000.

Indicate the Topic for which you are applying (check only one box).

- ☐ Natural Flow Regimes
- ☐ Nonnative Invasive Species
- ☐ Channel Dynamics/Sediment Transport
- ☐ Flood Management
- ☐ Shallow Water Tidal/ Marsh Habitat
- ☑ Contaminants
- ☐ Beyond the Riparian Corridor
- ☐ Local Watershed Stewardship
- ☐ Environmental Education
- ☐ Special Status Species Surveys and Studies
- ☐ Fishery Monitoring, Assessment and Research
- ☐ Fish Screens

What county or counties **is** the project located in? Contra Costa

What CALFED ecozone is the project located in? See attached list and indicate number. Be as specific as possible Sacramento-San Joaquin Delta #1. Mostly 1.2-1.4, but includes Suisun Bay 2.1.

Indicate the type of applicant (check only one box):

- ☐ State agency
- ☐ Public/Non-profit joint venture
- ☐ **Local** government/district
- ☐ University
- ☐ Other: ______
- ☑ Federal agency
- ☐ Non-profit
- ☐ **Tribes**
- ☐ Private party

Indicate the primary species which the proposal addresses (check all that apply):

- ☐ San Joaquin and East-side Delta tributaries fall-run chinook salmon
- ☐ Winter-run chinook salmon
- ☐ Springrun chinook salmon
- ☐ Late-fall run chinook salmon
- ☐ Fall-run chinook salmon
- ☑ Delta smelt
- ☐ Longfin smelt
- ☑ Splittail
- ☐ Steelhead trout
- ☑ Green sturgeon
- ☐ Striped bass
- ☑ White Sturgeon
- ☐ All chinook species
- ☐ Waterfowl and Shorebirds
- ☐ All anadromous salmonids
- ☑ Migratory buds
- ☐ American shad
- ☐ Other listed T/E species: ____________________

Indicate the type of project (check only one box):

- ☑ Research/Monitoring
- ☐ Watershed Planning
- ☐ Pilot/Demo Project
- ☐ Education
- ☐ Full-scale Implementation

Is this a next-phase of an ongoing project? Yes ✓ No —

Have you received funding from CALFED before? Yes ✓ No___

If yes, list project title and CALFED number____________________

Have you received funding from CVPIA before? Yes ___ No ✓

If yes, list CVPIA program providing funding, project title and CVPIA number (if applicable):

____

By signing below, the applicant declares the following:

- The truthfulness of all representations in their proposal;
- The individual signing the form is entitled to submit the application on behalf of the applicant (if the applicant is an entity or organization); and
- The person submitting the application has read and understood the conflict of interest and confidentiality discussion in the PSP (Section 2.4) and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in the Section.

Samuel N. Luoma

Printed name of applicant

SN Luoma

Signature of applicant

B. Executive Summary

TRANSPORT, TRANSFORMATION, AND EFFECTS **OF** SE AND CARBON IN THE DELTA **OF** THE SACRAMENTO-SAN JOAQUIN **RIVERS:** IMPLICATIONS **FOR** ECOSYSTEM RESTORATION.

Request: **$3,361,160.** Contact: ***S. Luoma, J. Cloern,*** *USGS,MS465,* ***345 Middlefield Rd., Menlo Park, CA 94025,*** *snluoma@usgs.gov;* ***650-329-4481,*** *FAX-X4545.* Co-PIs: , ***L. Lucas, J. Burau,*** *BG* ***Lee, R. Stewart,*** USGS, *S.* ***Monismith,*** Stanford U, *M.* ***Stacey,*** U. Calif. Berkeley, *G.* ***A. Cutter,*** *M. Doblin,* Old Dominion U., Norfolk, VA, *N. S.* ***Fisher,*** *S.* ***Baines*** **,** Mar. Sci. Res. Center, ***SUNY,*** Stony Brook ***NY.***

The Sacramento-San Joaquin Delta provides ecological and economic services of great significance to the entire Bay-Delta ecosystem. But important processes in the Delta are poorly understood. Many CALFED restoration alternatives involve changing inflows from the San Joaquin River (SJR) to the Delta and Bay, despite the impaired quality of SJR water. Great uncertainties exist about the effects of delivery of this poor quality water on Bay-Delta ecosystem restoration. The Delta is also a biogeochemical reactor that transforms materials after delivery and during transport to Suisun Bay. This function has direct influences on issues like the fate or trapping of pollutants (e.g. Se), drinking-water quality and native fish restoration. Carbon and selenium (Se) are two of the most important reactive elements in the Delta. Carbon is the universal currency of ecological energetics; biomass and production rates of biota are measured in carbon units, and used to construct foodwebs and calculate population growth rates. Some of the most contentious restoration issues in the Bay-Delta revolve around the potentially toxic element Se. Construction of new canals, reservoirs, barriers, and shallow-water habitats could all intentionally or unintentionally change the loading of Se to the Delta and/or the Bay, thereby countering otherwise beneficial effects. CALFED Category III is presently funding projects focused on C and on Se. They both identified transport through the Delta and transformations within the Delta as knowledge gaps that could limit plans for restoring Bay-Delta ecosystems. Rather than submit two independent requests for next-phase funding of these projects, we herein propose one integrated project in which the dynamics of Se are studied from a perspective that considers the carbon cycle in the Delta and incorporates use of a newly refined, hydrodynamic transport model for the Delta. We believe that this offers several potential avenues for rapid scientific advancement. It is a unique opportunity to take timely advantage of the momentum and the expertise used to make recent important advances in physical modeling of the Delta. It is also an opportunity to assemble an interdisciplinary project of nearly unprecedented scope, around an important problem. If Se and C are good scalars for refining the Delta transport model, the project will advance knowledge applicable to transport and transformation of other reactive substances found in the SJR, like nutrients and pesticides.

The overall objectives of this multi-faceted program of targeted research are: (1) Use newly developed approaches to determine, under a variety of conditions, how the Delta system transports and distributes conservative materials delivered from the rivers; **(2)** Evaluate transformations of Se and C in the Delta---within a transport context---and their consequent distributions; and (3) Determine how transport and transformation of Se will affect critical food webs in the Delta and the Bay. The project will deliver products that include: (1) Model forecasts of Se and C dynamics in the Delta under a variety of flow regimes, with and without biological transformation reactions; (2) Delta-scale verification of forecasts by monthly analyses and transects of water column Se and bioindicators; (3) Detailed knowledge of Se transformation and transport within critical habitats in the Delta, integrating 3D hydrodynamic models, physical experiments, detailed studies of water, sediment and bioindicators, and biouptake studies with local flora and fauna; (4) analysis, modeling and effects studies of Se within the Bay'and Delta food web. The outcome of the project will have applications to the many issues of relevance to CALFED that converge in the Delta, including long-contentious Se issues. Delta-scale, and local-scale physical, geochemical and

ecological models will be produced that will be directly applicable to evaluating solutions to those issues in the future.

C. Project Description

C.l. Problem/C1.a. Problem Statement

Results from OUT two Category 111 projects show that the dynamics of Se are tightly coupled to the dynamics of C. Questions about the inputs, transports, transformations, and foodweb incorporation of Se in the Delta simultaneously must consider the sources, transports, and trophic transfer of carbon.

Complex physical processes are part of the challenge of understanding the Delta. The interaction of tides with complicated geometry can result in dispersive transports of constituents that cannot be predicted with simple, one-dimensional models or with measures of net flow and mean concentration. Models that incorporate processes like tidal dispersion are computationally expensive, but recent advances in computer hardware make detailed simulations feasible for large spatial domains over hydrologically and ecologically relevant timescales (months). The recent successful demonstrations of Delta-wide and habitat-specific tidal-forcing models showed results that could not be predicted from other modeling approaches [53, 54]. The ability of the DELTA-TRIM hydrodynamic model to calculate transport of conservative tracers was verified by simulating a dye release conducted in 1997 [54, 56]. Salt transport simulations in 2D and 3D compared well with measurements [53]. It is now feasible to use this model to study more complicated constituents like Se and address how hydrologic conditions will affect the fate of Se in the Delta across a range of hydrologic regimes.

The chemical speciation of Se determines its fate, cycling and biological impacts (Fig. 1). Selenate (SeVI) is the principal dissolved form in imgation drainage (and in the rivers) although some organic selenide (Se -11) also is present. Selenite (SeIV) dominates oil refinery inputs, but little is present in other sources. Transformation of dissolved to particulate Se depends upon speciation. Within the Delta, transformation of selenate to elemental particulate Se(0) and particulate organic selenide occurs via microbial reduction [57] or uptake by primary producers. After transformation, Se can recycle back to the water column [14]. For example, dissolved organic selenide forms in pore waters and determines rates of flux to the water column from sediments [16]. Careful consideration of Se speciation and particulate transformation is critical to any successful study of the element. Se:C ratios also can be used to account for biogeochemical reactions of Se, and exclude mineral clays (which act essentially as a particle diluent). Knowledge of Se:C ratios in phytoplankton allow quantification of Se transformation by C productivity, and thus facilitate modeling influences of primary production on a Delta Se budget.

Transformations by primary producers are of special interest in the Delta because phytoplankton dominate some Delta habitats, aquatic macrophytes dominate others, and wetlands are common throughout. Comparisons of Se cycling among such habitats are rare; yet it is conceivable that cycling could differ dramatically, and some restoration outcomes might result in more Se problems than others. One of the important knowledge gaps is how the specific phytoplankton typical of the Delta might transform Se. Relevant information from the literature is limited and contradictory. Freshwater algae show saturation uptake kinetics for selenomethionine, but only some species do so for selenate and none for selenite [61]. Selenate is accumulated through the sulfate uptake pathway [63], so it could be more efficiently transformed by plants in the Delta than in estuarine waters. Uptake of selenite is better known than uptake of selenate [68, 25, 33] and it is clear that species differ greatly in their ability to accumulate selenite (Fig. 1). Organic selenides are an important form of the element, but studies of the their bioavailability are just beginning [68, 2,331. Organic selenide released by the alga *Aureococcus anophagefferens* after lysis by a virus was readily available to ***T. pseudonana*** [26], and Se in lysates of ***T. pseudonana*** is taken up by several other species at rates that are similar to those for selenite [1]. The long residence times of organic selenides in water columns suggest recalcitrant forms also exist, however. Studies of selenate and organic selenide uptake rates with a variety of local phytoplankton species are needed to model and understand Se transformations in the Delta.

Se concentrations, speciation, incorporation by algae and transformation in sediments will determine Se accumulation in the resident food web [49, 62]. Se magnifies in the food web as plants are eaten by their consumers and as consumers are eaten by their predators [49]. Small enrichments of Se in the Bay have resulted in substantial build-up in food webs, especially in benthivores [17, 35, 44]. Potential for adverse effects on upper trophic level species is the reason Se is of concern [41]. Understanding the effects of changes in future Se loads requires understanding how those loads might influence restoration of the Delta food web. This will involve identifying species critically sensitive to Se, either via elevated exposure or via physiological vulnerability to its effects. If benthivorous species are the most likely to be affected by Se, the greatest need is to understand how Se effects might be manifested in such species.

C.1b. Conceptual Model

The guiding questions of this proposal present a profound scientific challenge because they involve the interacting effects of diverse and complex physical, biological, and biogeochemical processes, most of which are not well characterized in the Delta. Figure 2 shows a general conceptualization of the problem, Figure 3 reflects the interrelationships among tasks, and Figure 1 is a conceptual model more specific to Se in the Delta. The simplest view of the problem begins with the loading of dissolved forms of Se from the SJR. If the forms of Se were unreactive, then their distribution would be determined by the flow paths of water parcels across the Delta. For this reason, our project includes a component of new field measurements and numerical modeling to characterize the' **Se** distributions in a transport framework, including the variability of flows and mixing processes. However we know that all chemical forms of Se can be transformed by biogeochemical processes, including C production. Understanding the fate and effects of Se requires consideration of both transport and transformation. One critical first step in the incorporation of dissolved ***Se*** into the foodweb is assimilation by the primary producers, i.e. the phytoplankton, into intracellular pools of organic selenide, primarily as amino acids and proteins. The rate of this biotransformation is proportional to the rate of primary production, which averages 47 tons of carbon per day for the entire Delta system [34]. After Se is transformed by phytoplankton, it is available for trophic transfer to primary consumers such as mesozooplankton (rotifers, cladocerans, copepods) and, especially, benthic invertebrates (clams, amphipods, insect larvae). Trophic transfer from consumers to their predators ultimately determines adverse effects of Se; reproduction is the process most likely to be affected in predators.

C.1c. Hypotheses:

What are the rates and pathways by which SJR-derived inputs **of** Se traverse the Delta? Hypotheses developed around models that predict Delta-scale distributions of Se and C will involve two steps: 1) utilizing the hydrodynamic model with non-reactive numerical "dyes" to estimate the simplest outer envelope of total Se transport (assuming it is conservative) under a range of hydrologic and water management scenarios; and 2) applying a coupled hydrodynamic-biogeochemical model in concert with localized field studies to understand on a local scale, then model on a Delta-wide scale, how reactions will modify dissolved Se transport and distribution. We will use this multi-faceted approach to answer a variety of questions. For example: Does the Delta act as a trap or a conduit for Se and are there places within the Delta where Se might be physically concentrated? What are the roles of primary forcings (tides, freshwater inflow, wind)? How does the routing and transport rate of Se change under different conditions of river flow, within-Delta consumptive use of water, exports, barrier placement or channel modification?

What are the rates and pathways by which SJR-derived inputs **of** Se are transformed by geochemical and biological processes within the Delta? We will use 3D local models and process studies in several specific Delta habitats along with monthly monitoring of those habitats and laboratory studies to determine

the dominant biogeochemical reactions that alter the speciation of Se and the rates of Se transformations relative to the rates of transport. We are also interested in whether gradients within habitats and differences in primary production within and among habitats affect Se transformation. We will incorporate simple water column transformations into the Delta-scale transport model from this knowledge. And we will use the sophisticated transport model to refine exchange rates in a sequential reactor box model (under development at ODU) which we will use to further understand the complex biogeochemical reactions of Se.
What are the effects **of** Se **on** critical species in the Delta and Bay food web?
We will use experiments, bioaccumulation models, and field measurements of stable isotopes and Se concentrations in food web organisms as bioindicators to answer questions about transfer of the Se concentrations and forms predicted from the above models into Delta food webs. Bioaccumulation by the dominant Delta consumer species will be a special concern, as will the question of what predators are most likely to be exposed to high concentrations of Se should loadings increase in the Delta (similarly, what organisms are least threatened is also important). From monitoring bioindicators we will evaluate if Se in the food web is changing as refinery Se inputs decline, water management changes and hydrology varies year-to-year. Finally we will continue the challenging studies of what predator exposure means: How will Se contamination of consumer species affect reproduction in critical predators in the Bay?
C.1d. Adaptive Management: This project will quickly improve our understanding of Delta hydrodynamics and thereby set the stage for vastly improved adaptive management with regard to issues that involve water movement, complex mixing and constituent transformations within the Delta. Poor knowledge of Delta hydrodynamics, carbon cycling and pollutant fate presently impedes many important decisions. For example, uncertainties about Se issues have paralyzed some decisions for decades, partly because it is recognized that mismanagement of Se issues could threaten the credibility of the restoration process. Creation of another "Kesterson Syndrome" [59] would be disastrous. Effective adaptive management must accompany any solution to the Se issues, but that will require powerful tools and reliable monitoring data to provide accurate feedback to managers. The specific studies proposed here will provide methods and data for on-going evaluation of the status of Se contamination, as well as feedback with regard to how specific restoration outcomes (phytoplankton-based habitat; macrophyte habitat; wetland habitat), or management decisions (more or less water from the SJR; construction of a master drain either out-of-valley or to the SJR) might affect Se threats to reproduction of species of concern. They will provide on-going multi-media monitoring of the status of Se contamination as issues change and a baseline against which to judge future changes. They extend regular data collection to new environments (three specific Delta habitats and the gradient from Carquinez Strait to Stockton). More important, the tools developed in this study (critical knowledge gaps and dramatically improved hydrodynamic, geochemical, biological and synthesis modeling tools), will be critical for evaluation of proposed future solutions to Se and other Delta-specific issues, as well as managing them for the optimum desired outcomes.
C.2. Scope **of work.**
C.2a. Geographic Boundaries. The project will be bounded by Vemalis on the SJR, Freeport on **the** Sacramento River (SACR), and Carquinez Strait. Hydrographic data, monthly samples and historical data from the boundary stations will be used to derive inputs and set up model boundary conditions. Interdisciplinary, coordinated process studies will be conducted within the Delta at Mildred Island (MI), Franks Tract (FT), and Threemile Slough (3MS). Primary production in MI may be dominated by phytoplankton and, in FT, by macrophytes; so the two offer a valuable comparison for the Se transformation studies. It is important to understand the ecology, physics and pollutant biogeochemistry of these habitats in order to enhance their abilities to produce fish. 3MS is an especially important connection between the major river systems and may deliver high Se concentrations to the SACR at some times [19].
C.2b. Approach.

Task 1. Modeling. To learn about the within-Delta processes which influence the distribution, storage, export, and fate of Se and C, modeling will be employed in concert with field experiments and analysis of existing hydrologic data sets. We will use a high-resolution hydrodynamic model to which transformation reactions for Se and C will be eventually added. First, we will use the hydrodynamic model on a Delta-scale to develop solute transport forecasts in the absence of reactions. This initial modeling phase will consider Se a conservative species and will provide an "outer envelope" for how much Se might move from the SJR to the Bay, or indicate where Se might concentrate in the Delta if governed purely by transport. This phase will help guide Se sampling on the Delta-scale. Second, we will couple simple biogeochemical submodels to the hydrodynamic code and employ the coupled model on a local scale in concert with process studies (simultaneous physical and biogeochemical) in the field. The field experiments will identify the dominant processes required of a Delta transport model, illuminate the mechanisms governing transformation of Se and C, and provide groundtruthing for the model. The model will also help **us** interpret the measurements. Third, after having refined the coupled model in the second phase, we will use the coupled model on a Delta-scale, to develop physics- and reaction-based forecasts of Se distribution, transformation, and export. Delta-scale modeling will address a variety of critical hydrologic regimes.

A. Hydrodynamic Modeling/No Reactions. The model to be used is "DELTA-TRIM," which is the TRIM3D hydrodynamics and transport code [6, 7] adapted for the Delta by Monsen [53]. DELTA-TRIM may be used in 3D or 2D depth-averaged mode. By pooling several sources of data, Monsen [53] developed a Delta bathymetry grid (Figure **4**) with approximately 150,000 horizontal grid cells (50 m resolution). DELTA-TRIM incorporates flow from the SACR and *SJR*, export pump operations, approximately 250 within-Delta agricultural diversions and returns, and gate and temporary barrier operations [54]. The ability of DELTA-TRIM to calculate transport of conservative tracers was verified by simulating a dye release conducted in 1997 [54, 56]. Salt transport simulations in 2D and 3D compared well with measurements [53]. See Figure 5 for hydrodynamic model details.

We will first use DELTA-TRIM in 2D mode and treat Se **as** a nonreactive "dye", to estimate an "outer envelope" of influence for different solute sources (e.g. ***SJR***) and for several hydrologic, barrier, and pump operation scenarios (see for example, Figure 6). For model verification and refinement, simulation results will be compared with the physical field experiments (in MI, FT, and 3MS). **This** will include comparisons with measured velocity fields and water surface elevation, dye concentrations and drogue tracks. Comparisons of 2D and 3D simulations with flux experiments in 3MS will indicate 1) whether DELTA-TRIM adequately predicts the potentially dominant process of tidal dispersion and complexities introduced by channel junctions and bends; and 2) whether the dominant transport processes may be captured with the more efficient 2D model. The ability of DELTA-TRIM to calculate hydraulic residence time in FT and MI will also be evaluated by comparison with dye experiments.

B. Local-scale Physical-Biogeochemical Modeling. Modeling of within-Delta biogeochemical transformations (with simultaneous transport) will use the DELTA-TRIM hydrodynamic model as the backbone, but with added equations for reactions involving dissolved Se and phytoplankton biomass (Figure 7). Goals include understanding: 1) the portion of the dissolved Se pool "stripped" off by phytoplankton within the Delta; 2) the relative amounts of phytoplankton-incorporated Se consumed by pelagic and benthic grazers; and 3) the physical-biogeochemical conditions which govern #1 and #2 above. See Figure 5 for details of the biogeochemical model. Application of the coupled model will first focus on comparisons with the process experiments (in 3MS, MI, and FT) for model verification, refinement, and interpretation of observations. Details of the hydrodynamic modeling approach, as well **as** Se and C transformation processes and parameterizations, will be evaluated and refined. Boundary conditions (including water surface elevation, phytoplankton biomass, and dissolved Se concentrations at open boundaries, and measured benthic grazing rates at the bottom boundary) and initial conditions (including spatial distributions

of phytoplankton biomass and dissolved Se) measured during the experiments will be applied in model runs. Other measurements factoring into the biogeochemical calculations include turbidity and temperature.
C. ***Delta-scale Physical-Biogeochemical Modeling.*** The physical-biogeochemical model developed and refined in the second modeling phase will be ultimately **used** on a Delta-scale for addressing the transport- and transfonnation-dependent distribution and storage of Se across the Delta, as well as export of Se to the Bay. The larger model domain will necessarily rely on larger-scale sampling efforts, including measured spatial distributions of and boundary conditions for phytoplankton biomass and Se, and measured Delta-wide distributions of benthic consumers of phytoplankton for calculating benthic grazing rates for the model. The latter will require one cross-Delta survey of the benthos (350 samples). (See Figure **5** for details.)
Task 2. Physical Experiments. Hydrodynamic experiments will be conducted in three localities (3MS, MI, and FT) to 1) identify and understand crucial Delta transport/export processes; **2)** verify DELTA-TRIM'S ability to capture the dominant transport processes; 3) refine the hydrodynamics code if necessary; **4)** provide hydrodynamic information for interpreting measured temporal and spatial variability of Se and C. Existing Delta hydrodynamic datasets will also be analyzed. These physical experiments as part of the integrated "process studies."
A. Threemile Slough–Flux and Hydrodynamic Structure in a Tidal Channel. Correctly capturing the flow in curved channels and junctions (ubiquitous in the Delta) is essential for predicting the net transport of a tracer like Se because even subtle asymmetries in the tidal flow in these regions can result in large net fluxes through the action of tidal dispersion. For example, the flow through 3MS---a connector between SACR and SJR---is driven by the difference in tidal phase between the two rivers. During periods of low flow, tidally-averaged water transport is directed toward the SJR. However, since the tidal excursion in 3MS is greater than the length of the Slough, water from the SJR is carried into the SACR with each tide. The resulting tidal dispersion causes net transport of substances (like Se) that have higher concentrations in the SJR than in the SACR to the SACR, despite the net water transport in the opposite direction (see Figure 8).

We will: (1) determine whether 3MS is an important conduit of Se into the SACR (2) characterize the three-dimensional structure of flows in channel bends and junctions and associated mixing; and (3) provide a three-dimensional data set of fluxes for calibrating and verifying DELTA-TRIM. Taken together, we are examining a critical aspect of Delta circulation---tidal dispersion in channel bends and junctions---in a location important to the distribution of Se in the Delta. We will conduct the 3MS study in fall, when the SJR comprises the largest fraction of Delta inflows. High Se concentrations at Rio Vista on the SACR coincided with this hydrologic condition in Oct. 1996 [19] (Fig. 9). Fixed instruments will collect 3-month timeseries of velocity and specific conductivity (SC), and therefore flux, at each end of 3MS. Cross-channel variability of velocity and SC (and therefore flux) will be measured in two locations, during different tidal phases, and during spring tide and neap tide. Tidal excursion and exchange with the rivers will be characterized by D-GPS drifters. A boat-mounted ADCP will quantify the evolution of 3D tidal flow in the bend and junctions (see Figure **10** for details).
B. Mildred Island and Franks Tract–Residence times in Shallow Water Habitats (SWH). Interior hydrodynamics, including hydraulic residence time, will be examined at MI and FT. The residence time of waters in both depends on: basin geometry; location, size and number of openings; density and distribution of vegetation; presence of wind-waves and wind-driven flows; and spatial and temporal variability of the above factors (e.g. the level of vegetation may vary seasonally and spatially). The hydrodynamic model does not currently account for the spatial or temporal variability of all these factors, and we will evaluate how important they are so that model improvement can be focused appropriately.

Tracking of a passive dye with a boat-mounted fluorometer will quantify the net exchange of fluid between interior basins and adjoining channels, and will allow a direct estimate of residence time. Dye measurements will be made from the R/V Compliance. D-GPS drifters will provide additional net transport data and also indicate visually where the dye is likely to be. Fixed instruments will measure net fluxes in and out of each SWH, as well as interior hydrodynamics. Density stratification, vertical velocity shear, and the effects of vegetation on turbulence structure will be measured. The SWH experiments will occur during summer to coincide with phytoplankton production and, in FT, Egeria growth. During each SWH experiment, additional moored instruments will be deployed at the levee breaches of the alternate SWH, for comparing consecutive summers if the two years present very different hydrologic conditions. (See Figures 11, 12 for details.)

C. Barrier Effects. Temporary flow barriers (which direct salmon smolts downstream) significantly affect southern Delta circulation and likely have a major impact on Se flux through the Delta. We will analyze 1997-98 USGS measurements [56] of the effects of barriers on south Delta flows, illuminating barrier-flow relationships and making model-field comparisons. This exercise will not require resources for data collection.

Task 3. Field Studies of Se Distributions and Transformation. Biogeochemical process studies---conducted simultaneously with hydrodynamic experiments (Task 2)---will be carried out within specific habitats (MI, FT, and 3MS). These experiments, conducted jointly with 3D modeling (Task 1B), will serve as a "microscope" for examining detailed interactions controlling transformations and distributions on a local scale. The process study data will help us refine our coupled model (Task 1B) so it can ultimately be used on a Delta-scale (Task 1C).

Se concentrations and speciation in the water column, suspended particulates and sediments [11, 12, 13, 15] will identify Se transformation pathways, integrate laboratory phytoplankton uptake experiments with *in situ* rates of Se transformations, refine model inputs, validate model outputs, and examine historical records of Se inputs to the Delta. Specific approaches include:

A. Suisun Bay-Delta transect cruises extending from Carquinez Strait to Stockton. In the first year the transects will examine the whole system during four seasons (high flow, intermediate flow preceding and following high flow, then low flow), in order to link to the Delta-scale model forecasts. The frequency of cruises in subsequent years will be determined by needs to differentiate seasonal differences or flow conditions. At least eight cruises will occur in the three year period. By simultaneously measuring the conservative tracers of salinity or chlorinity, we can calculate the rates and locations of Se transformation (i.e. fluxes; [17]), and use this information to refine our models.

B. Monthly collections of dissolved and particulate Se at sites in MI, FT and 3MS, coordinated with bivalve collections and changes in primary productivity. Samples of water and suspended particulates will be analyzed near monthly at one site in MI, FT and 3MS and at 2 sites in Suisun to identify changes in concentration and speciation of Se. Phytoplankton biomass distributions, phytoplankton composition and photosynthetic carbon fixation will also be determined. As primary production begins to increase in each year, biweekly samples will be collected in order to capture dynamics in detail [50]. Simultaneous determinations of Se in resident clams will evaluate coupling between plant-carbon dynamics, Se dynamics or transformations, and Se uptake by herbivores.

C. Detailed process cruises, with high resolution sampling over multiple tidal cycles in MI, FT and 3MS, coordinated with 3D modeling and deployment of physical instruments. At the same time that the instrumented physical experiments (Task 2) are underway, effects of uptake, regeneration and sediment-water flux of Se will be evaluated in samples collected on 2 day process cruises, with one study each in MI, FT and 3MS. Effects of transport and *in situ* biogeochemical processes will be separated by sampling dissolved and particulate Se concentration and speciation at 3 hour intervals, at three sites within the domain. Phytoplankton biomass is spatially heterogeneous in these habitats (Figure 13, [48]), so the phytoplankton gradient will be characterized during the study by high resolution mapping along predetermined circuits at different tidal phases (e.g. high slack, low slack) and during spring and neap tide. The R/V Compliance is equipped with instrumentation for continuously (every second) measuring and logging near-surface chlorophyll fluorescence, turbidity, temperature, dissolved oxygen, and conductivity, as well as GPS location. Benthic samples will be taken to estimate effects of benthic grazing on phytoplankton [9, 67, 46, 47], and thus ultimately on the fate of Se. **A** benthic sampling grid, developed from geostatistical techniques, model results and previous studies by DWR, will overlay the surface water sampling circuits. Regions of higher resolution will be included amongst an overall lower resolution sampling grid, to capture different scales of patchiness. For each of the three habitats, 50 benthic samples will be taken. Se fluxes either into or out of the sediments will be determined by taking sediment box cores and sampling pore waters near the same sites, allowing calculation of a Se budget for the system. These data will be essential for testing the accuracy of the model.

D. Collection of undisturbed sediment cores for establishing a historical record of Se inputs. Knowledge of historical Se trapping might aid forecasts of future responses in the Delta. **A** historical record of Se contamination in Delta sediments over the last 100 years will be obtained from box and gravity cores at 4 sites in the Delta where undisturbed sediments are accumulating. One site will be from Sherman Island as a reference. Cores will be radiotracer dated, and particulate Se concentration and speciation will be determined. We have located 2 sites that are suitable; 2 more will be located.

The biogeochemical studies will refine, for the Delta, a sequential reactor box model under development at ODU. In lieu of adequate computation capability for a Delta-scale physical-biogeochemical model with detailed biogeochemical processes, the box model will allow better understanding of complex biogeochemical interactions in a simpler physical context. The box model will improve biogeochemical inputs to the coupled 2D/3D model (Tasks 1B, 1C). The 2D/3D model will provide a logical basis for selection of boxes and improve the characterization of inter-box mass transfer, and exchange coefficients.

Task 4. Laboratory study of Se transformations by local phytoplankton. Se uptake kinetic parameters will be established for a range of different phytoplankton species important in the SF Bay-Delta, including freshwater and estuarine forms. Cells will be isolated from Suisun Bay, MI, and FT, and clonal, unialgal cultures will be established [29]. Cultures will be maintained in Fisher's laboratory in WCL_1 (freshwater) or f/2 (estuarine) media [30]. Dominant species in the upper bay include *Melosira granulata, Skeletonema potamos*, and *Cyclotella glomerata* (diatoms), *Nannochloris atomus*, *Chlamydomonas spp.*, and *Chlorella' spp.* (chlorophytes), the cyanophyte *Anabaena circinalis*, and the cryptophytes *Rhodomonas lacustris*, *Chroomonas spp.*, and *Cryptomonas erosa* [40, 8].

For each species, uptake kinetics of SeO_3, SeO_4, and organic selenides will be evaluated in cells during log-phase growth and senescence using the gamma-emitting isotope ^{75}Se [24]. This approach enables working rapidly with low, environmentally realistic Se concentrations. Radioactive SeO_3 and SeO_4 are commerically available. Radiolabeled organic selenides will be produced by growing the euryhaline diatom *Thalassiosira pseudonana* with ^{75}Se-labeled SeO_3 for at least 6 divisions (cells will be uniformly labeled), during which the cells convert the Se to seleno-amino acids [71, 3, 24]. The cells are then removed from their radioactive medium and broken through a series of freezing and thawing steps; the released cellular Se is in organic form [1]. Key Michaelis-Menten uptake parameters (K_m and V_{max}) will be determined for each combination of Se species, algal species and physiological state using developed protocols [24, 61, 1]. Se uptake can apparently vary greatly among species [43, 32], so we expect that Se transformation rates may differ if seasonal succession occurs in the phytoplankton assemblages.

Experiments will determine the Se:C ratios of algal species at different stages of growth. *C* uptake rates can be simultaneously assessed using standard $NaH^{14}CO_3$ uptake measurements. The release of Se and

C in exudates from each species will be measured by transferring growing and decomposing cells to unlabeled water and measuring the release of ^{14}C and ^{75}Se [39]. Exudation rates of organic Se from algae should reveal their roles in contributing to the organic selenide pool in SF Bay. These experiments will help determine the influence of phytoplankton on the Se budget in SF Bay and the extent to which different algal assemblages are sources of Se for key herbivores, many of which accumulate essentially all their Se through their diet [49, 70, 69].

Task 5 Se in Bay-Delta Food Webs Four approaches will be used to better understand Se in food webs:

A. Continued monitoring of Se in bivalves Se concentrations will be determined monthly, coincident with monthly water and suspended Se samplings, from samples (n=>50) of resident ***Potamocorbula amurensis*** from Carquinez Strait using established biomonitoring protocols (11), in order to **sustain** the time series of Se in ***P. amurensis*** effectively used to understand Se availability to food webs in the past [45]. Monthly monitoring of Se in the bivalve *Corbicula fluminea* will be initiated at MI, FT and 3MS coincident with monthly water column sampling (Se and phytoplankton), to characterize dynamics, trends and sources of bioavailable Se in the Delta. Again, established protocols are available [35].

B. Studies of Se distributions in the food web. Se will be determined in tissues from a large selection of species; stable isotopes will be used to evaluate feeding relationships (δ13C, 15N). Isotope analyses were added to the studies of Se in selected Delta organisms in the present study, and appear to be quite effective in separating even small differences in feeding strategy [66], if samplings are constrained within a narrow window of time and replicated (n–15). The present proposal will allow the MI food web (Figure 14) to be further sampled and understood. Interpretation of the combined isotope, Se concentration and kinetic data will be used to identify more and less sensitive components of the Delta food web, and identify where Se impacts might be expected.

C. Kinetics of Se bioaccumulation in consumer animals and their predators. Kinetic aspects of ***Se*** bioavailability (assimilation efficiency, uptake from water, loss rates) will be characterized for key species ***(Chironomus*** and amphipods), and for their predators, to develop species-specific bioaccumulation models. Pulse-chase techniques with radio-labelled Se will be used to determine assimilation efficiency, several food types will be compared, and experiments will use low, environmentally realistic Se concentrations. These approaches were successfully employed for ***P. amurensis, Macoma balthica, Corbicula fluminea,*** and ***Leptocheirus sp.*** [49, 62]. When the model parameters are combined with field measurements of stable isotopes, Se concentrations and form, we can forecast Se distribution across the consumer level of the food web under different conditions.

D. Effects on benthivores. Omnivores, plankton feeders and benthivores will be evaluated for use in trophic transfer-associated studies of effects on reproduction in species important to Delta restoration. One goal of this targeted research will be to develop general protocols that can be applied to evaluate impacts of concentrations predicted for future management decisions. The study of adverse effects from dietary exposures, especially on reproduction, are complicated, but are the only realistic approach to experimentally evaluating if or why a population might fail. We will select a prey species that can be exposed/cultured in the laboratory and fed ***en masse*** to predators in a three step food web transfer study. Predator response will be the endpoint; experiments will be constrained to study of growth in young fish or study of effects as predators begin to develop egg masses.

Task 6. Effects on Sturgeon. Mechanistic studies of Se effects on sturgeon will be extended. Late-stage vitellogenic white sturgeon females will be exposed to environmentally relevant and toxic levels of Se while held in outdoor 20 foot diameter tanks at ambient conditions. Oocyte formation will be evaluated along with Se content of oocytes, embryonic development and early development of the resulting juveniles. In this experiment, 10 randomly selected hatchery bred females will be fed Se-laden diet for the last two months of yolk deposition (vitellogenesis). The diet will contain **20** ug/g Se in the form of selenized yeast, which has been shown to contain mostly seleno-methionine. Following adequate time for oocyte maturation, we will induce spawning and collect the mature eggs, which should have Se incorporated into the yolk platelets [20, 21]. Subsamples will be analyzed for whole egg and yolk platelet Se content [36, 23]. The formation of the oocytes will be examined histologically. We will fertilize the eggs *in vitro* [20], and the development of the eggs will be intensively monitored. Subsamples will be taken at several stages throughout the gestation period and investigated for histopathological and enzymatic abnormalities [58, 4, 55, 66]. Viable embryos and resulting larvae will be reared and monitored for normal growth, organ development and signs of terata. Observed effects will be related to the Se exposure and content of the mature female.

The field component of this study will involve collections of spawned eggs from the Sacramento River [52]. The eggs will be transferred to the laboratory and reared *in vitro* [20]. The development of the embryos will be monitored as above and relationships evaluated between Se in the collected eggs and levels shown to produce adverse effects in eggs from the controlled studies. Lesions produced by Se in the laboratory will be compared with those in the field to verify Se as the causative agent.

C.2c. Monitoring and Assessment. The monthly data collection proposed here will extend a Bay "monitoring" time series of water column Se, bivalve Se and river-borne Se that began in 1986 [18, 19, 35, 45]. It will extend a Delta time series begun in 1998, from Carquinez to Stockton, the first rigorous time series of a pollutant from the Delta. This multi-media monitoring has influenced litigation, scientific studies and management decisions for 15 years; it is likely their continuation will also be influential.

C.2d,e. Data and Products. The co-PI's are committed to generating data and publications that are relevant, accessible, influential and understandable for the scientific community, water managers, and the public. All have a history of providing such service through presentations in a variety of academic and public settings and publication in the peer reviewed literature, CALFED white papers and syntheses for managers and the public. Full participation in CALFED science conferences will continue.

C.2f. The work schedule is shown in Figure 15, and milestones are listed in Table 1. The tasks are interwoven in time, space and objective. Each could be accomplished alone, of course, but alone each would be of greatly diminished value. Incremental funding of the entire project would be greatly reduced benefit; the cross-discipline nature of the study is critical to overall success.

C.2.g. Feasibility. The co-PI's on this study have stature, substantial experience and no vested interests in the local Se issues. The feasibility of the modeling, field studies and experimental approaches are demonstrated by their experience with each approach as cited in their peer-reviewed publications. The combination of high quality expertise that has been assembled (hydrodynamics, modeling, Se biogeochemistry, phytoplankton ecology, trace element fate and effects, sturgeon biology) is a very novel aspect of this proposal. All co-PI's have the facilities and experience to successfully accomplish what they are proposing. All required facilities are available and in operation (specifics available on request).

D.l. Applicability **to** CALFED **ERP.**

This proposal is critical to ERP Goals 1,2,3,4 and 6. Se is a toxic element that has impaired reproduction and prevented restoration of native benthivorous fish species in other' systems [31]. Benthivorous species that are designated species-at-risk, harvestable species or species in decline, in the Bay-Delta include native splittail, tule perch and sturgeon. Native species are likely to be of different vulnerability to Se, but most data suggests benthivores are especially at risk [66]. Delta smelt and salmon could also be at risk from Se; the food web study we are proposing will specifically address that issue. In the Bay, Se transfer is accentuated in bivalve food webs and is short-circuited by some zooplankton (which lose Se very rapidly and therefore do not accumulate high burdens). Fate in Delta food webs centers around the bivalve ***Corbicula,*** amphipods and chironomids; trophic transfer to and from these organisms is not well known. Quantitative comparisons of trophic transfer can allow identification of predator species most and least at risk, and may help explain specifically where Se is or could be an issue for wildlife restoration.

Water quality issues in the Bay-Delta (Goal 6) are constantly changing, requiring both vigilance and on-going study. Se is an excellent example. Refineries have reduced their Se inputs and concentrations in the water column have declined in Suisun Bay [19]. But other sources of Se input may be increasing or be affected by water management changes. Se is naturally enriched in the sedimentary soils of the western San Joaquin Valley (SJV), and is mobilized by irrigation practices [60]. Pressure is growing to resolve issues around salt and Se accumulation in SJV soils [72]. In addition, proposed management options for the Bay-Delta include physical changes to the Delta system, like construction of new canals, reservoirs, barriers, and shallow-water habitats, that could intentionally or unintentionally change the loading of Se into the Delta and the Bay, thereby countering otherwise beneficial effects of managing the SJR. It is critical to avoid mis-management of Se issues and avoid re-creation of conditions (in, for example, restored wetlands) that previously were referred to as ecological disasters (e.g. 'The Kesterson Syndrome" [59]). . **A** critical uncertainty in all potential solutions to disposal of irrigation drainage waters is the transfer of Se through the Delta; another is the potential transformation/trapping within the Delta. It is also not well known how much Se is trapped by the Delta under present water management conditions, although better understanding of present conditions could aid better predictions of outcomes should conditions change.

Se trends in predators like splittail, sturgeon, diving ducks, or dungeness crab are difficult to monitor with sufficient frequency, and difficult **to** interpret with regard **to** sources. Prey species, like filter feeding bivalves, are more feasible to monitor and can be indicative of trends in predator exposure to Se, since food is the primary route of predator uptake [41]. The multi-media (water and bivalve) monitoring that will be expanded by this study has already advanced understanding of water quality issues, and that will undoubtedly continue.

Finally the study will specifically address the effects of Se on benthivores reproduction and development, especially in white sturgeon, ***Acipenser transmontanus***. Se is a reproductive toxin that most threatens higher trophic level species because of its efficient food web transfer. White sturgeon spend the majority of their lives in the Delta and the adjacent northern section of this estuary (Suisun and San Pablo Bays) [37, 38] **,** and leave the bay to spawn in the upper river systems. **A** major food source of white sturgeon, the filter feeding bivalve ***Potamocorbula amurensis,*** contain significantly elevated levels of Se (avg.=15 ug/g *dry* **wt.)** [51]. Se concentrations in white sturgeon flesh have been measured at levels above those previously linked **to** reproductive impairment in birds and freshwater fish [42, 65,641. Nevertheless reproduction is very difficult to study in these fish because of their rare occurrence, their migratory behaviour and their long lives. White sturgeon populations are at risk, as evidenced by declining catch per unit effort. Long-term studies of reproduction are essential to adequately preserve these ancient fish; considering the potential additional stress of Se exposure should be **a** part of that determination.

D2. Next-phase funding. This is a joint request for next-phase funding of the ***two*** projects:

1997- B06 Assessment of Organic Matter in the Habitat and its Relationship to the Food Chain (J. Cloern, lead investigator)

98-2015000-00096–Assessment of the impacts of Se on Restoration of the San Francisco Bay-Delta Ecosystem (S. Luoma, lead investigator)

CALFED Category 111 is presently funding the above projects which are scheduled to end in 2001. Rather than submit independent requests for next-phase funding,'we herein propose one integrated project. As knowledge of food sources for Bay food webs and Se processes in the Bay-Delta have advanced it is now clear that transport within and through the Delta is **a** major knowledge gap. Recently, important advances have been made in physical modeling of the Delta, with the development of DELTA-TRIM [6, 7, 53]. This is a high resolution hydrodynamic model that incorporates tidal dispersion. It provides transport forecasts for conservative constituents and can include simple water column transformation reactions. Dispersive transports of constituents are observed that cannot be predicted with simple, one-dimensional models or with measures of net flow and mean concentration. Three-dimensional models of transport and reactions are also possible in specific Delta habitats. We are presented a timely opportunity to take advantage of the momentum and the expertise used to develop DELTA-TRIM in that Nancy Monsen and Prof. Monismith (Stanford) are willing to collaborate in this work to apply the model to non-reactive Se under various flow conditions and refine the model for use with reactions. Further, incorporation of phytoplankton dynamics into DELTA-TRIM has already begun (Lucas, Cloern). Thus, no time lags will occur in developing expertise with this sophisticated tool. Because water movement in the Delta, alone, is of paramount importance in many CALFED issues, and because C and Se are also at the center of critical Bay-Delta issues like water quality and restoration of native fishes, we believe this project offers several avenues for rapid scientific advancement.

Transformations of Se within the Delta were also not included in the earlier projects, **as** the initial work focused on exploring the Delta (from which no Se **data** existed previously) and understanding the Bay. It is now clear that Se transformations and'cycling are linked to the carbon cycle, so merging the Se and C projects seems logical. Both earlier CALFED studies were successful interdisciplinary studies of complex issues. In this proposal we have explicitly added detailed physics to the mixes of previous disciplines. All co-PI's have long experience in integrated, interdisciplinary studies, but we believe this team has capabilities rarely assembled and the experience and commitment for synergistic advancements on a difficult but important in mix of problems.

D.4. Previous CALFED funding: Progress

1997- B06 Assessment of Organic Matter in the Habitat and its Relationship to the Food Chain. This CALFED Category III Project is a collaboration between the USGS and University of California-Davis, Stanford University, and Virginia Institute of Marine Science. The project was designed to answer fundamental questions about the origin, quality, and quantity of the food resource available to support secondary production in the Delta and Suisun Bay. It was motivated by the alarming population declines of native species of zooplankton, and the hypothesis that biological production at the trophic level of zooplankton is limited by the food resource in some habitat types within the Delta. The project includes multiple approaches: analysis of historical data collected by the IEP to construct annual inventories of organic matter supply to the Delta; new field sampling to measure primary productivity and compare the quantity/quality/origin of the organic matter in different Delta habitat types; development and application of a hydrodynamic model to calculate transports of water and organic matter in the Delta; and field measurements to map the temporal and spatial variability of water-quality constituents in different shallow water habitats. **A** description of the overall project was published in the IEP Newsletter. Examples of progress include:

- Incubation assays of natural phytoplankton samples with C-14 were used to measure rates of primary production in different Delta habitats. Assay results were used to develop an empirical model to estimate the daily rate of primary production from simple measures of phytoplankton biomass (chlorophyll), turbidity, and daily irradiance.
- Analysis of historic IEP data indicates three important sources of bioavailable organic matter: (1) riverine inputs of labile dissolved organic carbon; (2) riverine inputs of freshwater phytoplankton, and **(3)** primary production by phytoplankton within the Delta. The relative importance of these different sources varies with river flow, seasonal gowth cycles of the phytoplankton, and Delta exports. Phytoplankton primary production contributes, on average, 47 tons of organic carbon per day to the Delta (this is the first estimate of Delta-wide primary production). Results of this analysis will be published in a paper in <u>Aauatic Conservation</u>.
- Zooplankton feeding assays demonstrate that secondary production can be food limited in the Delta. Laboratory-raised Daphnia were exposed to natural seston samples from different habitats, and rates of

growth and egg production were measured over five days. These assays show that the growth and reproduction rates of Daphnia are highly correlated with food availability, indexed as phytoplankton biomass. These experiments provide the strongest empirical evidence of a tight trophic linkage between phytoplankton and zooplankton production in the Delta. Preliminary results were published in an IEP Newsletter article and presented at the 2000 IEP Annual Meeting by Anke Mueller-Solger.

- **A** 3D hydrodynamic model **was** developed to simulate tidal-scale and residual transports in the Delta-Suisun Bay. The model has been calibrated with time-series of stage and currents, and used to estimate residence times of water in different habitats and flow conditions, to estimate the source mixtures of water in different Delta habitats, and to calculate flow paths of transport. Results were presented at the 2000 **IEP** Annual Meeting by Nancy Monsen. Incorporation of phytoplankton dynamics into this model is underway.
- High-resolution spatial mapping ***of*** chlorophyll concentration in Franks Tract and Mildred Island demonstrated large spatial variability of phytoplankton biomass, both between and within these shallow-water domains. Spatial variability is a result of the balance between the net phytoplankton source (primary production – grazing) and tidal-scale transports. These results show large differences among shallow water habitats as sources of phytoplankton biomass. They were presented at the 2000 IEP Annual Meeting by Lisa Lucas.

Impact of Se on Restoration of SF Bay. Twice per year transects of dissolved and particulate Se concentrations and speciation in water, suspended sediments and bed sediments (during high and low river inflow) were conducted since 1995 along with periodic box cores and monthly determinations of Se concentrations in resident bivalves (*Potamocorbula* ***amurensis).*** Refineries reduced their inputs to less than one-half the original load of Se by stripping selenite from their effluents by July 1998. Dissolved Se concentrations and speciation responded dramatically to changes in refinery inputs. The peak of selenite that once occurred near Carquinez Strait has disappeared. Total dissolved concentrations have also declined. Temporal and spatial patterns of particulate Se concentrations are variable, however. Particulate concentrations were particularly high in Oct. 1996 (1.5 – 8 μg Se/g), and gradients suggested a Delta source was important. Later transects in fall did not repeat these results, but high off axis concentrations are observed occasionally. The complexity of the data may reflect complex turnover of organic material in the estuary. Despite the variability, on average, particulate concentrations appear to have declined along the axis of the estuary since 1998. Total Se concentrations in bed sediment are relatively low (0.3 – 0.6 μg/g) compared to suspended particulate concentrations. But Se/C ratios are similar between the bed sediments and suspended sediments, so dilution with larger inorganic particles may play a role in the dilution of bed sediment concentrations. Pore water concentrations in sediments indicate that ***Se*** is being transformed there, but fluxes are not sufficient to explain water column concentrations (thus dissolved concentrations are not sustained by historic Se stored in sediments).

Se concentrations in bivalves (*Potamocorbula* ***umurensis)*** have not declined since the refinery clean-up, nor have spatial patterns changed greatly. High concentrations (10 – 20 μg/g *dry* **wt.)** are common in the low flow season, but concentrations decline to 5 – 10μg/g *dry* **wt** during high inflows (dissolved and particulate Se are also lower in high flow conditions). Dynamic, multi-pathway bioaccumulation models were developed from experiments with **P.** ***umurensis*** (DYMBAM). Experiments showed very high assimilation of Se from algal cells, as also seen in other bivalves. Se concentrations in *P. amurensis* might be facilitated by high assimilation from most foods, slow loss of Se, and particulate Se concentrations **of** 1.5 – **3** μg/g dry **wt** . The cause of the temporal de-coupling of **the** decline in dissolved and suspended particulate but not yet bivalve Se has not been resolved. Because temporal or spatial variability in particulate concentrations could be a cause, monthly sampling of water column Se was begun in Dec. 1999 at two stations near Carquinez Strait.

Se concentrations in the Bay food web organisms differ widely. Concentrations in zooplankton (previously unknown) range from 0.5 – 6.0 µg/g *dry* wt, lower than concentrations in clams. Experiments showed that zooplankton short-circuit Se transport **through** the pelagic food web because they lose Se **very** rapidly. Se uptake by phytoplankton can be extremely efficient in some species, but hardly occurs in others (Figure 16). Thus succession of phytoplankton species could cause some of the variability in transformation to particulate forms in estuaries. Phytoplankton may also have relatively invariable Se:C; thus responses to changes in environmental Se concentrations **within** species may be small. The coupling of Se **to** C **through** the phytoplankton is very important in the Bay-Delta. Samples of a wide range of food web organisms from Grizzly Bay have been collected to evaluate the effects of Se exposure, feeding relationships (determined by stable isotopes) and uptake kinetics on food web distributions. Most samples are in the process of being analyzed. Water, sediment and food web Se concentrations have also been analyzed twice from the Delta (the first such data from **this** system), but interpretations are not complete. Four hundred juvenile white sturgeon were obtained and a nontoxic feeding experiment with Se in white sturgeon was conducted in order to develop protocols and characterize background **ranges** of health parameters. **A** ninemonth juvenile toxicity experiment involving feeding regimes of 15, 30 and 45 ug/g Se is presently underway.

E. Qualifications

Samuel N. Luoma

Education: 70, BS, MS, Zoology, Montana State U.,; 74, PhD Marine Biology, Dept. Zoology, UHawaii,;
Experience: 1976, Project Chief; 1992 Senior Research Hydrologist, US Geological Survey, Menlo Park, CA; 1985-87 Chief, Br Western Region Res, USGS Menlo Park;
Advisory **Positions**: Editorial Adv. ***Marine Ecology Progress Series;*** Editor, ***Marine Environmental Research;*** Chair, Sci. Adv. Gp, Interagency Ecological Program; SAC, Ctr Environmental Health Res. UC Davis; SAC, Coastal Tox Prog., UC Toxic Substances Res Prog., USEPA Sci Adv. Bd-Sediment Quality Criteria; NAS, NRC - Contam. Bioavailability Soils & Sediment.
Research Interests: Fate, bioavailability, trophic transfer of trace elements; Influence of contaminants on biological & ecological processes; Ecology and water quality of SF Bay; broad interest in Environ. Sci.
Publications: (From –150 peer reviewed publications, some pubs relevant to **this** project): Lee B.-G., et al, S. N. Luoma, N. S. Fisher. 2000. ***Science,*** 287,282-285; van Geen, A.& Luoma, S. N. 1999. Specl. issue of ***Marine Chemistry*** 64, 1 - 128. Luoma, S. N., van Geen, A., Lee, B.-G., & Cloern, J. E. 1998 ***Limnology & Oceanography,*** 43, 62-67. Luoma, S. N., 1996 ***J. Exptl. Mar. Biol. Ecol.*** 200: 29-55. Luoma, S. N. & Fisher, N. S. 1997 ***In Ecological Risk Assessments of Contaminated Sediments,*** SETAC Press, Pensacola. Luoma, S.N. 1995, ***In Metal Speciation and Bioavailability,*** **John** Wiley & Sons, p. 610-659. Luoma, S.N., Johns C., Fisher N. S., Steinberg N. A., Oremland R. S. & Reinfelder J. 1992 ***Environ Sci Technol.,*** 26, 485-491. Nichols, F. H., Cloem, J. E., Luoma, S. N., & Peterson, D. H. 1986. ***Science*** 231,567-573. Luoma, S. N. 1984, ***Introduction to Environmental Issues,*** 1984, Macmillan Publ. Co. 549 pp.

Nicholas S. Fisher

Present Position: Professor and Associate Dean, Marine Sciences Research Center, State University of New York, Stony Brook, ***NY*** 11794-5000. Telephone/Fax/Email: (631) 632-8649/ 632-8820/ **nfisher@notes.cc.sunysb.edu**
Education: B.A., Biology, Brandeis University, 1970; Ph.D., Biology, SUNY, Stony Brook, 1974.
Previous Positions: Assoc. Prof., MSRC 1988-90; Oceanographer, Brookhaven Natl Lab 1986-87; Research Scientist, Marine Environment Lab, Intl Atomic Energy Agency, Monaco 1980-85; Senior Research Scientist, Ministry for Conservation, Melbourne, Australia '77-80
Research Interests: physiological ecology of plankton; biogeochemical cycling of metals in **marine** systems; trophic **transfer** of elements in marine food webs; marine radioecology; pollutant cycling and impacts **on** marine ecosystems.
Publications: Author of over 130 peer-reviewed publications, including many involving the bioaccumulation and trophic transfer of Se. Representative papers include: Fisher, NS. 1986. ***Limnol. Oceanogr.*** 31: 443-449; Fisher, **NS,** JK Cochran, S Krishnaswami, HD Livingston. 1988. ***Nature*** 335: 622-625; Reinfelder, JR, NS Fisher. 1991. ***Science*** 251: 794-796. (Winner of 1993 ASLO Lindeman Award); Fisher, NS, J-L Teyssié, SW Fowler, W-X Wang. 1996. ***Environ. Sci. Technol.*** 3 0 3232-3242; Wang, **W-X,** NS Fisher. 1999. ***Environ. Toxicol. Chem.*** 18: 2034-2045; Roditi, HA, **NS** Fisher. 1999. ***Limnol. Oceanogr.*** 4 4 1730-1749; B-G Lee, SB Griscom, J-S Lee, HJ Choi, C-H **Koh, SN** Luoma, NS Fisher. 2000. ***Science*** 287: 282-284; Fisher, NS, I Stupakoff, SA Sañudo-Wilhelmy, **W-X** Wang, J-L Teyssié, **SW** Fowler, J Crusius. 2000. ***Mar. Ecol. Prog. Ser.*** 194: 211-218.

Stephen B. Baines

Present Position: Res. Asst. Prof, MSRC, *SUNY*, Stony Brook, ***NY*** 11794-5000. Education: B.A., Biology, Drew University, 1985; Ph.D., Biology, Yale University, 1993. Research Interests: physiological ecology of plankton; comparisons of freshwater and marine ecosystems. Representative publications: Baines, SB, ML Pace. 1991. Limnol. Oceanogr. 36: 10784090; Baines, SB, ML Pace, DM Karl. 1994. Limnol. Oceanogr. 39: 213-226; Baines, SB, KE Webster, TK Kratz, SR Carpenter, JJ Magnuson. 2000. Ecol. 81: 815-825.

Gregory A. Cutter

Present Position: Professor, Dept Ocean, Earth, and Atmospheric Sciences, Old Dominion University, Norfolk, VA 23529-0276. Voice: 757-6834929; Fax: 757-683-5303; gcutter@odu.edu

Education: 1977, B.A., Chemistry; UC, San Diego; 1982, Ph.D., chemistry; UC, Santa Cruz

Research Interests: Processes affecting trace element speciation and distributions in natural waters and sediments; paleoceanographic tracers; analytical methods for aquatic chemistry; computer modeling of geochemical processes.

Selected Publications: (From more than 50 peer-reviewed, the following are representative Se publications) Cutter, G.A. 1982. Science 217: 829-831; Cutter, G.A. and K.W. Bruland. 1984. Limnol. Oceanogr. 29: 1179-1192; Cutter, G.A. 1989. ***Estuarine*** Coastal *Shelf Sci.* 28: 13-34. Cutter, G.A. and M.L.C. San Diego-McGlone. 1990. ***Sci. Total Environ.*** 97: 235-250; Velinsky, D.J. **and** G.A. Cutter. 1991. Geochim. Cosmochim. Acta 5 5 179-191; Cutter, G.A. 1992. ***Mar.*** Chem., **40** 65-80; Cutter, G.A. 1993. ***J.*** Geophys. Res., 98: 16,777-16,786; Cutter, G.A and **L.S.** Cutter. 1995. ***Mar.*** Chem., **49** 295-306; Bowie, G.L., **J.G.** Sanders, G.F. Riedel, C.C. Gilmour, D.L. Breitburg, G.A. Cutter, and D.B. Porcella. 1996. ***Water Air Soil Pollut.*, 90**: 93-104; Rue, E.L., G.J. Smith, G.A. Cutter, and K.W. Bruland. 1997. *Deep-Sea Res.*, 44: 113-134; Cutter, G.A. and L.S. Cutter. 1998. ***Mar.*** Chem., 61:.

Martina A. Doblin

Present Position: Research Assoc. Prof, Dept. Ocean, Earth & Atmospheric Sciences, Old Dominion University, Norfolk, VA 23529-0276. Ph: (757)683-5980; Fax: (757)683-5303; Email: mdoblin@odu.edu

Education: B.Sc. (Hons.), Ecology & Evolutionary Biology, Monash University, 1992; Ph.D., Plant Science, U. Tasmania, 1998.

Research Interests: Speciation and biogeochemical cyclig of trace elements; physiological ecology of plankton.

Representative uublications: Doblin, M.A., Blackbum, **S.I.** and Hallegraeff, G.M. 2000. *J.* ***Plankton*** Res. 22(3):421-432; Doblin, M.A., Blackbum, S.I., and Hallegraeff, G.M. 1999. J. *Plankton Res.* 21(6):1153-1169; Doblin, M.A., Blackburn, S.I. and Hallegraeff, G.M. 1999. *J. Exp.* ***Mar.*** *Biol.* Ecol. 2363347.

James Cloern is a senior research scientist **at** the U.S. Geological Survey, with 24 years of experience directing a team study of the San Francisco Bay-Delta system. He received a PhD in aquatic ecology from Washington State University, and serves as a member of the Science Advisory Group to the IEP. Awards include a Fulbright Senior Scholar Award and the U.S. Department of Interior Meritorious Service Award. A relevant publication: Cloem, J.E., 1996. Phytoplankton bloom dynamics in coastal ecosystems: A review with some general lessons from sustained investigation of San Francisco Bay, California: Reviews of Geophysics, **34** (2):127-168.

Jon Burau is a project chief with the U.S. Geological Survey, with 15 years of experience studying the hydrodynamics of **North** Bay and the Delta **through** numerical model development and application and through field data collection and analysis. A relevant publication: Burau, J.R., S.G. Monismith, M.T. Stacey, R.N. Oltmann, J.R. Lacy, and D.H. Schoellhamer, 2000. Recent research on the hydrodynamics of the Sacramento-San Joaquin River Delta and **North** San Francisco Bay. Interagency Ecological Program Newsletter, Vol. 13, No. 2., p.45-55.

Lisa Lucas is a research scientist at the U.S. Geological Survey, with an emphasis on modeling physical-biological interactions in tidal systems. She received her Ph.D. in environmental fluid mechanics from Stanford University's Dept. of Civil and Environmental Engineering. Relevant publication: Lucas, L.V., J.R. Koseff, J.E. Cloem, S.G. Monismith, J.K. Thompson. 1999. Processes governing phytoplankton blooms in estuaries. I: The local production-loss balance, II: The role of horizontal transport. Marine Ecology Progress Series, 187:1-15, 17-30.

Stephen Monismith is a professor of Civil and Environmental Engineering at Stanford University and director of the Environmental Fluid Mechanics Lab there, with 13 years of experience in laboratory, numerical and field studies of estuarine hydrodynamics and physical-biological interactions. He received his PhD in Hydraulic Engineering at U.C. Berkeley. He was awarded an NSF Presidential Young Investigator in 1989. He serves on the IEP science advisory group and is an associate editor of Limnology and Oceanography. A relevant publication: Monisrnith, S.G., Burau, J. and M. Stacey, 1996, "Stratification

Dynamics and Gravitational Circulation in Northern San Francisco Bay" in San Francisco Bay: The Ecosystem, ed. T. Hollibaugh, pp. 123-153, AAAS.

Mark Stacey is an assistant professor in the department of Civil and Environmental Engineering at the University of California, Berkeley with an emphasis in environmental fluid mechanics. He received his Ph.D. from Stanford University and his research has focused on the physics of stratfied tidal flows, primarily estuaries. He is a member of the Bay-Delta Modeling Forum and has been active in the San Francisco Bay research community for 7 years. A relevant publication: Stacey, M.T., Monismith, S.G., and Burau, J.R. 1999. Observations of Turbulence in a Partially Stratified Estuary, Journal of Physical Oceanography, 29:1950-1970.

Janet Thompson is a research scientist at the U.S. Geological Survey, with 28 years of experience studying the benthic community of the San Francisco Bay-Delta system. She has degrees in biology and marine biology, and received a PhD in civil and environmental engineering from Stanford University. A relevant publication: Thompson, J. K., 1999. The effect of infaunal bivalve grazing on phytoplankton bloom development in South San Francisco Bay. PhD Thesis, Stanford University.

F. Cost.

Full budgets in CALFED format are shown in Tables B1-B6.

Written Budget Justification.

The co-PI's considered submitting 5 or 6 separate proposals to CALFED for the project proposed above, but realized that a combined proposal would be more cost-effective and, most important, be an unprecedented opportunity for a unified truly cross-discipline of several issues critical to CALFED. Thus, this project includes new measurements, analyses, and model-development that will build from a history of collaboration between USGS, Stanford, SUNY, UC Berkeley, ODU and UC Davis.

The USGS-Menlo Park request includes salary support for a postdoctoral associate (Monsen) who will take entire responsibility for Task 1A and partial responsibility for Tasks 1B and 1C. Also requested is partial salary support for USGS employees Lucas 10% (Tasks 1B, 1C, 3B, 3C), Cloern 5% (Tasks 1B, 1C, 3B, 3C), and Thompson 5% (Task 1C, 3C) for three years. Laboratory analysis of benthic samples will be contracted to an established benthic ecology lab. Two years of salary support for a GS-9 biologist and supplies are requested for some laboratory and statistical analysis of benthic samples and analysis of IEP zooplankton data/calculation of grazing rates (Tasks 1B, 1C, 3C). Funding for multi-processor PC's is requested for computationally expensive high-resolution Delta-scale hydrodynamic/biogeochemical simulations, so that multiple simulations may run at any one time (Task 1). Travel to the study site and scientific meetings for Lucas, Monsen, and the GS-9 is requested. Funds are requested for all three years for one non-permanent GS-7 govt. technician who will be in charge of local logistics, to conduct and help with sample collection and data generation for monthly sampling, transects and for process studies in Task 3 . Although food web studies and experimental studies for bioaccumulation model (Task 5) will continue in the 2001 these will be covered by previous funding for Andrea Robin Stewart and (partially) for Byeong Gweon Lee from CALFED , 1998. In 2002 and 2003 funds are requested for salary for Dr. Lee to continue development of the laboratory protocols and food web bioaccumulation models and for a half-time post-doctoral associate to finish Dr. Stewart's food web analysis. We are requesting a gamma well counter ($20,000) for radioisotope studies of Se assimilation by predators like small fish.

The Stanford budget request includes 1 month/year salary, and partial logistical support, travel, and supplies for Monismith, a hydrodynamics expert who will be advising on hydrodynamic modeling (Task 1).

The UC Berkeley budget request includes 1 month/year salary, benefits, and logistical support for Stacey, who will be designing hydrodynamic field experiments (Task 2A, 2B) and advising a postdoctoral associate and graduate student, who will be planning and conducting the experiments and analyzing field data (Task 2A, 2B, 2C). The postdoctoral associate will be primarily responsible for Tasks 2A and 2B, while the graduate student (for whom this research will comprise his/her thesis research) will concentrate on Task 2C. Salary support is requested for the postdoctoral researcher (100% for 2.67 years) and graduate student (100% for 2.5 years). The majority of equipment costs is for a SonTek "Hydra" for determining the hydrodynamic effects of vegetation and wind-waves (Task 2C). Other equipment costs are for computer hardware. Supplies and expendables include marine-grade materials for deployment frames for field instrumentation.

The USGS-Sacramento's budget for Task 2 includes 2 months of Burau's salary to analyze the data and write the necessaryreports in the 3rd year. Boat and captain costs for all field work (Tasks 2,3, and **4)** is included in this budget.

Cutter and Doblin fiom ODU will be in charge of Task 3 . One month of summer salary for the senior PI (Cutter) is requested for the three years of the project. Cutter will participate in field sampling (particularly at the start), be in charge of the biogeochemical modeling efforts, and will oversee other participants. Doblin is a research faculty, and 8 months of salary in Years 1 and 2, and ***6*** months in Year 3 are requested. Doblin will be in charge of the day-to-day operation of the biogeochemistry, will participate in most of the field work, perform all of the suspended particulate and field-based phytoplankton selenium determinations, as well as associated data analyses, and focus on linking the ODU biogeochemical field studies with the lab- and field-based biological work by SUNYSB and USGS. Six months of salary for a Senior Technician in Years 1 and 2, and four months in Year **3,** are required for the project, to perform analyses, coordinate logistics and participate on all of the field work, compile data, and oversee the undergraduate lab technician. This work will also represent a substantial portion of the Ph.D of a Graduate Research Assistant. Funds are requested for an Undergraduate Laboratory Assistant who will prepare/clean all of the sample containers, prepare reagents, and assist in sample preparation before analyses. The lab supplies budget is based on considerable experience with the highly technical nature of water column and sediment determinations of selenium and field work in the San Francisco Bay and Delta. The supplies include sample containers, reagents, glassware, peristaltic pumps and tubing, filters, and sediment sub-coring equipment and supplies (e.g., glove bags, nitrogen), monies for shipping equipment and samples, and publication/page charges in Year 3. Due to the considerable amount of field work in Years 1 and 2 (Delta transects; process cruises; historical coring survey), travel costs include monies for six Virginia-California sampling trips for 3 people (some combination of one PI, senior technician, and GRA) in Years 1 and ***2,*** and two trips in Year **3.** Travel monies for the PI's and GRA to attend one national (ASLO) or CALFED meeting to present results of this work, and PI coordination meetings are budgeted in Years 2 and 3.

Funds are requested fiom ***SUNY*** for Fisher (2 months/year) who will be responsible for the overall success of Task **4** and for Baines (4 months/year) who will be involved in all aspects of the research. Baines is a Research Assistant Professor at the Marine Sciences Research Center **(SUNY)** and will help design, conduct, and interpret the proposed experiments. Funds are requested for one Ph.D. level graduate student who will use this work as the centerpiece of his/her dissertation. We request funds in Year 1 to purchase one dedicated large capacity incubator ($5,000) for conducting these experiments with radiolabeled cultures. We also request $12,000 for the purchase of a Turner Designs IO-AU fluorometer and computer interface for monitoring the growth of algal cultures and field measurements of chlorophyll a. In Year 1, we also request funds for the purchase of two microscopes ($2,500 each), listed under expendable supplies. Expendable supplies also include radioisotopes, dedicated glassware, polycarbonate membrane filters and filtration apparatuses, radioisotope sample tubes, acids for decontamination, and appropriate biochemicals. We also request $1,000 for each of Years **2** and 3 to cover publication charges and $3,500/year to help cover costs associated with a service contract for one of the gamma counters to be used in this work. We request $7,000/year to support travel, which will include periodic trips between Stony Brook and Menlo Park, CA, travel associated with field trips for collections of water and organisms, as well as participation in a national meeting each year to present the results of our work. Indirect costs are calculated as 50.5% of total direct costs (minus capital equipment) for on campus work (75%) and 26% of off campus work (25%).

Cost Sharing: The modeling proposed here will focus interpretations on the Delta, although the seaward boundary is Carquinez Strait. Complex, 3D processes control hydrodynamics in Suisun Bay. This proposed project will leverage the investments of the USGS Place-Based study of hydrodynamics, contaminants and sediments centered in Grizzly Bay. That project is a >$1 million per year effort that integrates contaminant studies (including details Se sampling in the field), biological studies (including food sources or C cycling), sediment studies and physical experiments in the Grizzly Bay system. So simultaneously we will be conducting interdisciplinary studies that develop 2D-3D hydrodynamic models in the Delta and 3D hydrodynamic models in Grizzly Bay. Ultimately the two projects together should allow combined models and interpretations for the linked Delta – Suisun Bay system

The proposed studies in the Delta will use a base of established infrastructure to take advantage of the connections and experience working in SF Bay and the Delta of the several co-PI's . Vessels to be used in the hydrodynamic experiments (R/V Turning Tide, R/V Holly Day Bamett, R/V Mudslinger) are contributed by the USGS Sacramento District (net replacement cost $630,000). Use of the R/V Compliance (with onboard instrumentation for continuous near-surface water quality sampling, GPS, and data logging) for hydrodynamic, biological and biogeochemical sampling will be contributed by the U.S. Bureau of Reclamation. Several oceanographic instruments will be contributed by the USGS Sacramento District (8 ADCP (plus two ship-mounted), 14 velocity meters, 36 CTD, 21 acoustic releases, 37 transponders, 22 frames, 7 autosamplers, 2 yo-yo buoys, misc. hardware) totaling $828,400 in replacement value. Coring will be contributed from the USGS RV David Johnston. USGS-Menlo Park will contribute supplies, logistical support, and salary support for Luoma (10%), Cloern (10%), Lucas (65%), and Thompson (5%), and some supplies and complete logistical support for the postdoctoral associates (total $440,000). Two months per year of Burau's salary will be donated by USGS-Sacramento for annual field work and supervision of that work. UC Berkeley will be contributing 0.5 month/year salary and benefits for Stacey for 3 years (total $19300). Berkeley will also contribute a SonTek "Hydra" instrument package (replacement cost $33,000). ODU will contribute existing automated Se sampling apparatus and glassware for use in the field collections, as well as instrumentation and other facilities for state-of-the-art Se analyses, Professor Vincenzo Casulli of the University of Trento, Italy, is permitting us to continue to use his TRIM3D code free-of-charge for this project (value $100,000). The yearly contributions are:

	2001	**2002**	**2003**
USGS-Menlo Park	139,391	153,287	144,856
USGS-Sac. District	800,000	800,000	60,000
UC Berkeley	22,8 13	22,939	6,569
ODU	10,000	10,000	10,000
USGS Place-Based Studies, Suisun Bay	–1,000,000	–1,000,000	–1,000,000

Literature Cited
[1] Baines, S.B., N.S. Fisher, M. Doblin, G.A. Cutter. 1999. Uptake of dissolved Se by phytoplankton: is organic Se readily incorporated and do uptake rates differ among taxa?" Proc. ASLO Ann. Mtg.

[2] Besser, J.M., J.N. Huckins, and R.C. Clark 1994. Separation of Se species released fiom Se-exposed algae. Chemosphere 29: 771-780.

[3] Brown, T., and A. Shrift. 1982. Se: toxicity and tolerance in higher plants. Biol. Rev. 57: 59-84.

[4] Buege, J.A. and S.D. Aust, 1978. Microsomal lipid peroxidation. Meth. Enzymol. 52:302-310.

[5] Burau, J.R., S.G. Monismith, and J.R. Koseff. 1993. Comparison of advective transport algorithms with an application in Suisun Bay, a sub-embayment of San Francisco Bay, California. In: H.W. Shen, S.T. Su, and F. Wen (eds), Hydraulic Engineering '93, ASCE, New York, pp. 1628-1634.

[6] Casulli, V. 1990. Numerical simulation of shallow water flow. In: G. Gambolati, A. Rinaldo, C.A. Brebbia, W.G. Gray, and G.F. Pinder (eds), Computational Methods in Surface Hydrology, Springer, Berlin, pp. 13-22.

[7] Casulli, V. and R.T. Cheng. 1992. Semi-implicit finite difference methods for three-dimensional shallow water flow. International Journal for Numerical Methods in Fluids, V. 15, pp. 629-648.

[8] Cloern, J.E. unpubl., Unpublished data fiom the on-going, 1998 CALFED C study,

[9] Cloern, J.E. 1982. Does the benthos control phytoplankton biomass in South San Francisco Bay? Marine Ecology Progress Series, V. 9, pp. 191-202.

[10] Cloern, J.E., C. Grenz, and L.V. Lucas. 1995. An empirical model of the phytoplankton chlorophyll carbon ratio---the conversion factor between productivity and growth rate. Limnology and Oceanography, V.40, No. 7, pp. 1313-1321.
[11] Cutter 1978.

[12] Cutter, G. A. 1982. Selenium in reducing waters. Science 217: 829 – 831.

[13] Cutter 1983.

[14] Cutter, G.A., and K.W. Bruland, 1984, The marine biogeochemistry of selenium: A re-evaluation, Limnology and Oceanography, Vol 29., p. 1179-1192
[15] Cutter 1985.

[16] Velinsky, D. J. and Cutter, G. A. 1991. Geochemistry of selenium in a coastal salt marsh. Geochim. Cosmochim. ACTA 55: 179 - 191.

[17] Cutter, G.A., 1989, The estuarine behaviour of selenium in San Francisco Bay: Estuarine, Coastal and Shelf Science, v. 28, p. 13-34.

[18] Cutter, G.A., and M.L.C. San Diego-McGlone, 1990, Temporal Variability of Se fluxes in San Francisco Bay, Sci. Total Environ. 97/98:235-250.

[19] Cutter et al. in progress. Unpublished data fiom the on-going, 1998 CALFED Se study.

[20] Doroshov, S. 1985. Biology and Culture of Sturgeon Acipenseriformes. In J. Muir and R. Roberts (eds.), Recent Advances in Aquaculture, Vol. 2, pp. 251-274. Croom Helm, London & Sydney.

[21] Doroshov, S., G. Moberg, and J. Van Eenennaam. 1997. Observations on the reproductive cycle of cultured white sturgeon, *Acipenser transmontanus*. Environmental Biology of Fishes, 48:265-278.

[22] Edmunds, J.L., K.M. Kuivila, B.E. Cole, and J.E. Cloern. 1999. Do herbicides impair phytoplankton primary production in the Sacramento-San Joaquin River Delta? In: D.W. Morganwalp and H.T. Buxton (eds), U.S. Geological Survey Toxiic Substances Hydrology Program—Proceedings of the Technical Meeting, March 8-12,1999, Vol. 2, **U.S.** Geological Survey Water-Resources Investigations Report 99-4018B, West Trenton, New Jersey, USA, pp. 81-87.

[23] Fan, **T.** 2000. Micro Nitric Acid Digestion for Se Analysis. Personal Communication

[24] Fisher, N.S., and J.R. Reinfelder. 1991. Assimilation of Se in the marine copepod Acartia tonsa studied with a radiotracer ratio method. Mar. Ecol. Prog. Ser. 70: 157-164.

[25] Fisher, N.S., and M. Wente. 1993. The release of trace-elements by dying marine-phytoplankton. Deep-sea Res. 40: 671-694.

[26] Gobler, C.J., D.A. Hutchins, N.S. Fisher, E.M. Cosper, and S.A. Sanudo-Wilhelmy. 1997. Release and bioavailability of C, N, P, Se, and Fe following viral lysis of a marine chrysophyte. Limnol. Oceanogr. 42: 1492-1504.

[27] Gross, E.S., J.R. Koseff, and S.G. Monismith. 1999a. Three-dimensional salinity simulations of South San Francisco Bay. Journal of Hydraulic Engineering, **V.** 125, No. 11, pp. 1199-1209.

[28] Gross E.S., J.R. Koseff, and S.G. Monismith. 1999b. Evaluation of advective schemes for salinity simulations. Journal of Hydraulic Engineering, V. 125, No. 1, pp. 32-46.

[29] Guillard, R.R.L. 1973. Methods for microflagellates and nannoplankton. In: Handbook of Phycological Methods (J.R. Stein, ed.), Cambridge University Press, London, pp. 69-85.

[30] Guillard, R.R.L. 1975. Culture of phytoplankton for feeding marine invertebrates. In: Culture of Marine Invertebrate Animals (W.L. **Smith** and M.H. Chanley, eds.), Plenum, New

[31] Hamilton, S.J., 1999, Hypothesis of historical effects from selenium on endangered fish in the Colorado River Basin, Hum. And Eco. Risk Assess., Vol. 5, p. 1153-1180.

[32] Harrison, P.J., P.W. Yu, P.A. Thompson, N.M. Price, and D.J. Phillips. 1988. Survey of Se requirements in marine phytoplankton. Mar. Ecol. Prog. Ser. 47: 89-96.

[33] Hu, M.H., Y.P. Yang, J.M. Martin, K. Ym, and P.J. Harrison. 1997. Preferential uptake of Se(IV) over Se(VI) and the production of dissolved organic Se by marine phytoplankton. Mar. Environ. Res. 44: 225-231.

[34] Jassby, A.D. and J.E. Cloem. 2000. Organic Matter Sources for the Upper San Francisco Estuary (California, USA). Aquatic Conservation (in press).

[35] Johns, C., Luoma, S.N., and Elrod, **V.,** 1988, Selenium accumulation in benthic bivalves and fme sediments of San Francisco Bay, the Sacramento-San Joaquin Delta, and selected tributaries, *Estuarine,* ***Coastal and*** *Shelf Science*, 27: 381-396.

[36] Ihnat, M. 1974. Collaborative study of a fluorometric method for determining Se in foods. J. Assoc. of *Anal.* Chem., 57.

[37] Kohlhorst, D. 1980. Recent trends in the White sturgeon popu lation in California's Sacramento-San Joaquin Estuary. Calif Fish and Game, 66:210-19.

[38] Kohlhorst, D., L. Miller, and J. Orsi. 1980. Age and growth of White sturgeon collected in the Sacramento-San Joaquin Estuary, California: 1965-1970 and 1973-1976. Calif Fish and Game, 66:83-95.

[39] Lee, B.-G., and N.S. Fisher. 1992. Degradation and elemental release rates from phytoplankton debris and **their** geochemical implications. Limnol. Oceanogr. **3 7** 1345-1360.

[40] Lehman, P.W. 1996. Changes in chlorophyll a concentration and phytoplankton community composition with water-year type in the upper San Francisco Bay estuary. In: San Francisco Bay: The Ecosystem (J.T. Hollibaugh, ed.), Proc. 75th Ann Mtg. Pac. Div. AAAS, San Francisco, pp. 351-373.

[41] Lemly, A.D. 1985. Toxicology of selenium in a freshwater reservoir: Implications for environmental hazard evaluation and safety. ***Ecotoxicology and Environmental Safety*** 10: 314-338.

[42] Lemly, A.D., 1992. Teratogenic effects of Se in natural populations of freshwater fish. Ecotoxicol. Environm. Safety 26181-204.

[43] Lindstrom, K. 1983. Se as a growth factor for plankton algae in laboratory experiments and in some Swedish lakes. Hydrobiologia 101: 35-48.

[44] Linville, R. , S. N. Luoma, L. Cutter, G. A. Cutter. Selenium in the Invasive Bivalve ***Potamocorbula amurensis*** in the San Francisco Bay-Delta: Spatial Distribution, Temporal Variability and Comparisons to Other Species ***Aquatic Toxicology,*** in review.

[45] Linville, R. , S. N. Luoma, L. Cutter, G. A. Cutter. Selenium in the Invasive Bivalve ***Potamocorbula amurensis*** in the San Francisco Bay-Delta: Spatial Distribution, Temporal Variability and Comparisons to Other Species ***Aquatic Toxicology,*** in review.

[46] Lucas, L.V., I.R. Koseff, J.E. Cloern, S.G. Monismith, and J.K. Thompson. 1999. Processes governing phytoplankton blooms in estuaries. I: The local production-loss balance. Marine Ecology Progress Series, V. 187, pp. 1-15.

[47] Lucas, L.V., J.R. Koseff, S.G. Monismith, J.E. Cloem, and **J.K.** Thompson. 1999. Processes governing phytoplankton blooms in estuaries. II: The role of horizontal transport. Marine Ecology Progress Series, V.187, pp. 17-30.

[48] Lucas, L.V., J.E. Cloem, and J.K. Thompson. Local dynamics plus transport in shallow tidal habitats: **Lessons** for restoration and monitoring. (in prep.)

[49] Luoma, S.N.; Johns, C.; Fisher, N.S.; Steinberg, N.A.; Oremland, R.S. and J.R. Reinfelder. 1992. Determination of Se bioavailability to a benthic bivalve from particulate and dissolved pathways. Environm. Sci. Technol. 26:485-491.

[50] Luoma et al. 1998

[51] Luoma, S. N. and Linville, R. 1996. Distribution, fate and effects of selenium and related contaminants in North San Francisco Bay/Delta and its food web. Rept. To Regl. Water Quality Control Board.

[52] McCabe, G. T. 1990. Use of an Artificial Substrate to Collect White Sturgeon Eggs. California Fish and Game, 76:248-250

[53] Monsen, N.E. 2000. A study of subtidal transport in Suisun Bay and the Sacramento-San Joaquin Delta, California. Ph.D. Thesis, Stanford University.

[54] Monsen, N.E. and S.G. Monismith. Fall 1999. Calibration and verification of Delta TRIM. IEP Newsletter, V. 12, No. **4,** pp. 28-35.

[55] Ohrloff, C.; Hockwin, **O.**; Olson, R. and S. Dickman, 1984. Glutathione peroxidase, glutathione reductase and superoxide dismutase in the aging lens. Curr. Eye Res. 3:109-115.

[56] Oltmann, R. 1999. Measured **flow** and tracer-dye data for Spring 1997 and 1998 for the **South** Sacramento-San Joaquin Delta, California. IEP Newsletter, V.12, No. 3, pp. 37-44.

[57] Oremland, R. S.; Steinberg, N. A.; Maest, **A** S.; Miller, L. G.; Hollibaugh, J. T. 1990. Measurement of in situ rates of selenate removal bly dissimilatory bacterial reduction in sediments. Environ. Sci. Technol. 2 4 1157 - 1164.

[58] Owens C.W.I. and R.V. Belcher, 1965. A colorimetric micro-method for the determination of glutathione. Biochem. J. 94705-711.

[59] Presser, T.S. and Ohlendorf, H.M., 1987, Biogeochemical cycling of selenium in the San Joaquin Valley, California, USA: Environmental Management, vol. 11, p. 805-821.

[60] Presser, T.S. and Piper, D.Z., 1998, Mass balance approach to selenium cycling through the San Joaquin Valley, sources to river to bay *in* W. Frankenberger and R.A. Engberg, eds., Environmental Chemistry of Selenium, Marcel Dekker Inc., New York, p. 153-182.

[61] Riedel, G.F., D.P. Ferrier, and J.G. Sanders. 1991. Uptake of Se by freshwater phytoplankton. Water Air Soil Poll. 57/58: 23-30.

[62] Schlekat, C., Lee, B-G, and S. N. Luoma.

[63] Shrift, A. 1954. Sulfur-Se antagonism. I. Anti-metabolite action of selenate on the growth of *Chlorella vulgaris*. Am J. Bot. 4: 223-230.

[64] Skorupa, J. P. M., Sarah P; and Judy S. Selfchick-Edwards. 1996. Guidelines for Interpreting Se Exposures of Biota Associated with Nonmarine Aquatic Habitats. U.S. Fish and Wildlife Service, Sacramento.

[65] Stanley, T.R.; Smith, G.J.; Hoffman, D.J.; Heinz, G.H. and R. Rosscoe, 1996. Effects of boron and Se on mallard reproduction and duckling growth and survival. Environm. Toxicol. Chem. 15:1124-1132.

[66] Stewart et al. in progress. Unpublished data from the on-going, 1998 CALFED Se study.

[66] Thomas, P. and H.W. Wofford, 1993. Effects of cadmium and aroclor 1254 on lipid peroxidation, glutathione peroxidase activity, and selected antioxidants in Atlantic croaker tissues. Aquat. Toxicol. 27:159-178.

[67] Thompson, J.K. 1999. The effect of infaunal bivalve grazing on phytoplankton bloom development in South San Francisco Bay. Ph.D. Thesis, Stanford University.

[68] Vandermeulen, J., and A. Foda. 1988. Cycling of selenite and selenate in marine-phytoplankton. Mar. Biol. 98: 115-123.

[69] Wang, W.-X., and N.S. Fisher. 1998. Accumulation of trace elements in a marine copepod. Limnol. Oceanogr. 43: 273-283.

[70] Wang, W.-X., N.S. Fisher, and S.N. Luoma. 1996. Kinetic determinations of trace element bioaccumulation in the mussel Mytilus edulis. Mar. Ecol. Prog. Ser. 140 91-113.

[71] Wrench, J.J., 1978. Se metabolism in the marine phytoplankters *Tetraselmis tetrathele* and *Dunaliella minuta*. Mar. Biol. 49:231-236.

[72] Presser, T.S. and Piper, D.Z., 1998, Mass balance approach to selenium cycling through the San Joaquin Valley, sources to river to bay *in* W. Frankenberger and R.A. Engberg, eds., Environmental Chemistry of Selenium, Marcel Dekker Inc., New York, p. 153-182.

Table 1. Milestones.

Date	Milestone
Jan. 2001	Start project, begin to hire needed personnel
Jan. 2002	Model results: Se transport without reactions under different hydrologic regimes
Jun 2002	1.Data available: Se concentrations from transects and monthly water column in 2001 2.Data available MI study...geochemical, physical, model results 3.Data available ***P. amurensis*** and C. fluminea from 2001 4. Manuscript written on food web & Se in MI 5. Verbal presentation of results for CALFED staff as requested.
Jun 2003	1.Data available: Se concentrations from transects and monthly water column in 2002 2.Data available FT study.. .geochemical, physical, model results 3.Data available ***P. amurensis*** and C. fluminea from 2002 4. Manuscript on phytoplankton transformation reactions 5. Manuscrivt on bioaccumulation by invertebrate vredators **6.** Verbal synthesis on any aspect requested by CALFED staff.
Jan 2004	1.Manuscript on Se cycling in Bay-Delta and biogeochemical modeling. 2.Data available 3MS study...geochemical, physical, model results 3.Data available ***P. amurensis*** and C. fluminea from 2003 4. Manuscript incorporating reactions and physics into Delta-Scale transport model 5. Manuscript on protocols for toxicity testing via dietary exposure to Se. **6.** Manuscript defining Se effects on sturgeon reproduction. **7.** Cross-discispline manuscript on model-biogeochemistry-transformation-food web in Delta habitats. 8. Synthesis paper on Se in Bay-Delta completed.

Table B1											
CALFEDIL Budget for (partial) USGS-MP, SUNY, ODU											
						Subject to Overhead					
Year	Task	Direct Labor Hours	Salary	Benefits	Travel	Supplies & Expendables	Overhead Rate	Overhead	Equipment		Total Cost
Year 1											
ODU	Task3		$78,410	$18,486	$12,000	$14,500	42.50%	$52,443			$175,839
SUNY	Task4		$52,500	$52,500	$7,000	$19,500	44.00%	$39,079	$17,000		$144,144
USGS	Task5		$28,835	$19,982		$5,000	53%	$39,123	$20,000		$112,940
Project Management		1% outside						$3,200			$3,200
Total Cost Year 1											
Year 2											
ODU	Task3		$82,060	$19,467	$12,000	$12,500	42%	$52,931			$178,958
SUNY	Task4		$54,675	$9,786	$7,000	$15,500	44%	$38,589			$125,549
USGS	Task5		$109,891	$26,465		$11,000	53%	$78,099			$225,455
Project Management		1% outside						$3,045			$3,045
Total Cost Year 2											
Year 3											
ODU	Task3		$70,937	$16,108	$7,000	$10,000	42%	$43,698			$147,741
SUNY	Task4		$57,333	$10,615	$7,000	$15,500	44%	$40,136			$130,584
USGS	Task5		$109,891	$26,465		$3,000	53%	$73,859			$225,455
Project Management		1% outside						$2,783			$2,783
Total Cost Year 3											
Total Project Cost											$1,475,693

Table B2

CALFEDII Budget for (partial) USGS-Menlo Park (Cloern, Monsen, Lucas, Thompson)

Year	Tasks (1, 3)	Direct Labor Hours	Salary	Benefits	Travel	Supplies & Expendables	Service Contracts	Equipment	Overhead (53.5%)	Total Cost
2001	Monsen GS12-1 (100%)	2088	$57,200	$17,747					$41,214	$116,161
	Lucas GS13-2 (10%)	210	$6,807	$2,110	$2,000				$5,953	$16,870
	Cloern ST01 (5%)	105	$6,493	$909					$4,016	$11,418
	Thompson (5%)	105	$3,404	$1,055					$2,441	$6,900
	Mulltiple-Processor PC							$40,000	$21,400	$61,400
	Biologist GS9-1 (100%)	2088	$39,474	$0	$2,000	$4,000			$25,446	$70,920
	Contract for Benthos Analysis 250 samples						$37,500		$20,063	$57,563
Total Cost Year 1			$113,378	$21,821	$4,000	$4,000	$37,500	$40,000	$120,533	$341,231
2002	Monsen GS12-2 (100%)	2088	$62,700	$19,437	$1,500				$45,8631	5129,5001
	Lucas GS13-3 (10%)	210	$7,697	$2,386	$2,000				$6,577	$18,660
	Cloern ST01 (5%)	105	$6,883	$964					$4,254	$12,101
	Thompson (5%)	105	$3,849	$1,193					$2,753	$7,795
	Biologist GS9-1 (100%)	2088	$43,237	$0	$2,000	$4,000			$27,459	$76,696
	Contract for Benthos Analysis 250 samples						$37,500		$20,063	$57,563
Total Cost Year 2			$124,366	$23,980	$5,500	$4,000	$37,500		$106,969	$302,314
2003	Monsen GS12-3 (100%)	2088	$68,610	$21,269	$1,500				$50,005	$141,384
	Lucas GS13-4 (10%)	210	$8,413	$2,608					$6,009	$17,030
	Cloern ST01 (5%)	105	$7,296	$1,021					$4,506	$12,823
	Thompson (5%)	105	$4,207	$1,304					$3,004	$8,515
Total Cost Year 3			$84,319	$24,898	$1,500	$0	$0		$60,519	$171,236
Total Cost			$322,062	$70,699	$11,000	$8,000	$75,000	$40,000	$288,020	$814,781

"able B3

:ALFEDII Budget lor USGS-Sacramento

Year	Task	Direct Labor Hours	Salary	Salary: Leave assessment, Report costs	Travel	Supplies & Expendables	Equipment	Vessel Costs	Overhead (69%)	Total Cost
			Subject to Overhead							
Year 1	Task 2 - Purchase Equipment		$0	$0	$0	50	$102,600	$0	$91,580	$194,180
2001	Task 2 - Physical Experiments									
	2b - Mildred Island	1168	$34,272	59,600	52,000	$11,650	$0	$2.550	553,619	5113,691
	2a - Three Mile Slough	816	524,207	$6,500	$0	$4,700	$0	$4,200	$35,352	$74,959
	Task 3 - Bio/Chem Experiments	40	$1,001	5398	$0	$0	$0	$750	$1,913	$4,063
	Task 4 - Bio/Chem Monitoring	96	$2,403	$961	$0	$0	$0	$1,800	$4,276	$9,061
'otal Cost Year 1			$61,863	$17,459	$2,000	$16,350	$102,600	$9.300	5166,740	$395,974
Year 2	Task 2-Physical Experiments									
	2b - Franks Tract	1272	$40,907	$11,200	$2,000	$10,475	50	53,600	$60.858	$129,040
	Task 3 - Bio/Chem Experiments	40	51,141	5453	$0	50	$0	$750	$2,086	$4,429
	Task4 - Bio/Chem Monitoring	96	$2,739	51,095	$0	$0	$0	$1,800	$5,014	$10.646
'otal Cost Year 2			$44,787	$12,746	$2,000	$10,475	$0	$6,150	$67,958	$144,117
Year 3	Task 2-Analysis and Reports	520	$24,121	$5,800	$0	$0	$0	$0	$26.707	$56,628
'otal Cost Year 3			$24,121	$5.800	$0	$0	$0	$0	$26,707	$56,626
'otal Project Cost			$130,791	$36,007	$4,000	$26,625	5102,600	$15,450	$261,405	5596,719

Table B4

CALFEDII Budget for UC Berkeley

Year	Task	Direct Labor Hours	Salary	Benefits	Travel	Supplies & Expendables	Service Contracts	Overhead (50.4%)	Equipment	Graduate Student Fee Remission	Total Cost
			Subject to Overhead						Exempt from Overhead		
Year 1	Task 2	2958	$58,940	$7,708	$1,000	$5,000	$0	$36,615	$33,000	$2,576	$144,839
Total Cost Year 1			$58,940	$7,708	$1,000	$5,000	$0	$36,615	$33,000	$2,576	$144,839
Year 2	Task 2	3567	$70,317	$8,046	$2,000	$1,000	$0	$41,007	$0	$5,345	$127,715
Total Cost Year 2			$70,317	$8,046	$2,000	$1,000	$0	$41,007	$0	$5,345	$127,715
Year 3	Task 2	2871	$57,804	$5,841	$2,000	$1,000	$0	$33,589	$0	$5,746	$105,980
Total Cost Year 3			$57,804	$5,841	$2,000	$1,000	$0	$33,589	$0	$5,746	$105,980
Total Project Cost			$187,061	$21,595	$5,000	$7,000	$0	$111,211	$33,000	$13,667	$378,534

Table B5

CALFEDII Budget for Stanford

Year	Task	Direct Labor Hours	Subject to Overhead						Exempt from Overhead		
			Salary	Benefits	Travel	Supplies & Expendables	Service Contracts	Overhead (60 %)	Equipment	Graduate Student Fee Remission	Total Cost
Year 1	Task 1		$9,961	$2,400.57	$2,000	$1,000	$2,000	$10,417	$5,000		$32,778
Total Cost Year 1	Task 1		$9,961	$2,401	$2,000	$1,000	$2,000	$10,417	$5,000	$0	$32,778
Year 2	Task 1		$10,359.32	$2,497	$2,000	$1,000	$2,000	$10,714	$0	$0	$28,569
Total Cost Year 2	Task 1		$10,359	$2,497	$2,000	$1,000	$2,000	$10,714	$0	$0	$28,569
Year 3	Task 1		$10,774	$2,596	$2,000	$1,000	$2,000	$11,022	$0	$0	$29,392
Total Cost Year 3			$10,774	$2,596	$2,000	$1,000	$2,000	$11,022	$0	$0	$29,392
Total Project Cost			$31,094	$7,494	$6,000	$3,000	$6,000	$32,153	$5,000	$0	$90,740

Table B6.													
							Subject to Overhead						
Year	Task	Direct Labor Hours	Salary	Benefits	Travel	Supplies & Expendables	Service Contracts	Overhead Rate	Overhead	Equipment	Vessel Costs	Graduate Student Fee Remission	Total Cost
Year 1													
ODU	Task3		$78,410	$18,486	$12,000	$14,500		42.5%	$52,443				$175.839
SUNY	Task 4		$52,500	$52,500	$7,000	$19,500		44.0%	$39,079	$17,000			$144,144
USGS-MP	Task 5		$28,835	$19,982		$5,000		53.0%	$39,123	$20,000			$112,940
USGS-MP	Task 1, 3		$113,378	$21,821	$4,000	$4,000	$37,500	53.0%	$120,533	$40,000			$341,231
USGS-Sac	Task 2,3,4		$61,883	$17,459	$2,000	$16,350		89.0%	$186,740	$102,600	$9,300		$395,974
Berkeley	Task 2		$58,940	$7,708	$1,000	$5,000	$0	50.4%	$36,615	$33,000		$2,576	$144,840
Stanford	Task 1		$9,961	$2,401	$2,000	$1,000	$2,000	60.0%	$10,417	$5,000	$0		$32,778
Project Management		1% outside							$4,976				$4,976
Total Cost Year 1													
Year 2													
ODU	Task 3		$82,060	$19,467	$12,000	$12,500		42.0%	$52,931				$178,958
SUNY	Task 4		$54,675	$9,786	$7,000	$15,500		44.0%	$38,589				$125,549
USGS-MP	Task 5		$109,891	$26,465		$11,000		53.0%	$78,099				$225,455
USGS-MP	Task 1, 3		$124,366	$23,980	$5,500	$4,000	$37,500	53.0%	$106,969				$302,314
USGS-Sac	Task 2,3,4		$44,787	$12,748	$2,000	$10,475		89.0%	$67,958		$6,150		$144,117
Berkeley	Task 2		$70,317	$8,046	$2,000	$1,000	$0	50.4%	$41,007			$5,345	$127,715
Stanford	Task 1		$10,359	$2,497	$2,000	$1,000	$2,000	60.0%	$10,714				$28,569
Project Management		1% outside							$4,608				$4,608
Total Cost Year 2													
Year 3													
ODU	Task3		$70,937	$16,106	$7,000	$10,000		42.0%	$43,698				$147,741
SUNY	Task4		$57,333	$10,615	$7,000	$15,500		44.0%	$40,136				$130,584
USGS-MP	Task 5		$109,891	$26,465		$3,000		53.0%	$73,859				$225,455
USGS-MP	Task 1, 3		$84,319	$24,898	$1,500	$0	$0		$60,519				$171,236
USGS-Sac	Task 2,3,4		$24,121	$5,800	$0	$0	$0	89.0%	$26,707				$56,628
Berkeley	Task 2		$57,804	$5,841	$2,000	$1,000	$0	50.4%	$33,589			$5,746	$105.980
Stanford	Task 1		$10,774	$2,596	$2,000	$1,000	$2,000	60.0%	$11,022				$29,392
Project Management		1%outside							$4,137				$4,137
Total Cost Year 3													
Total Project Cost													$3,361,160

Figure 1

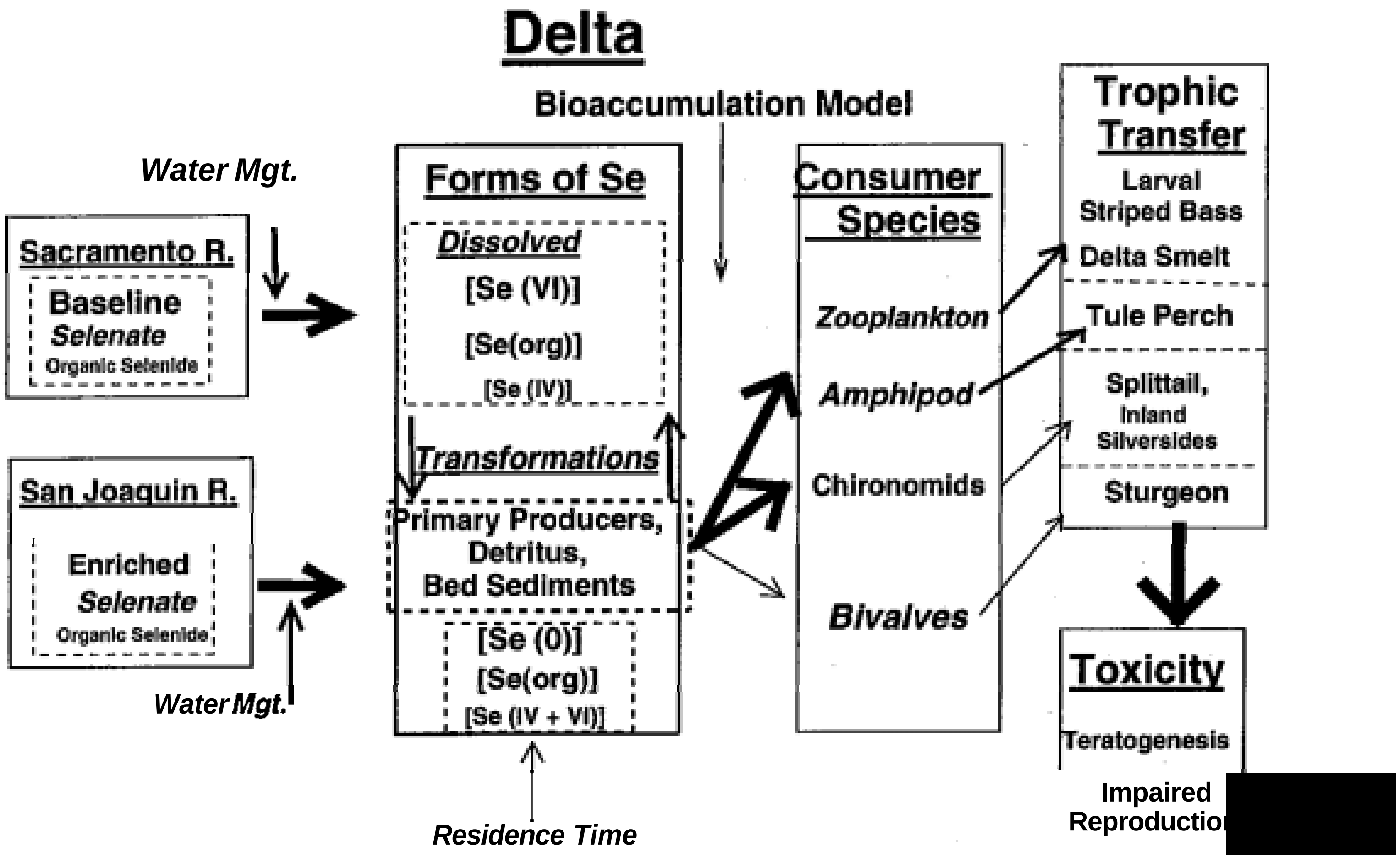
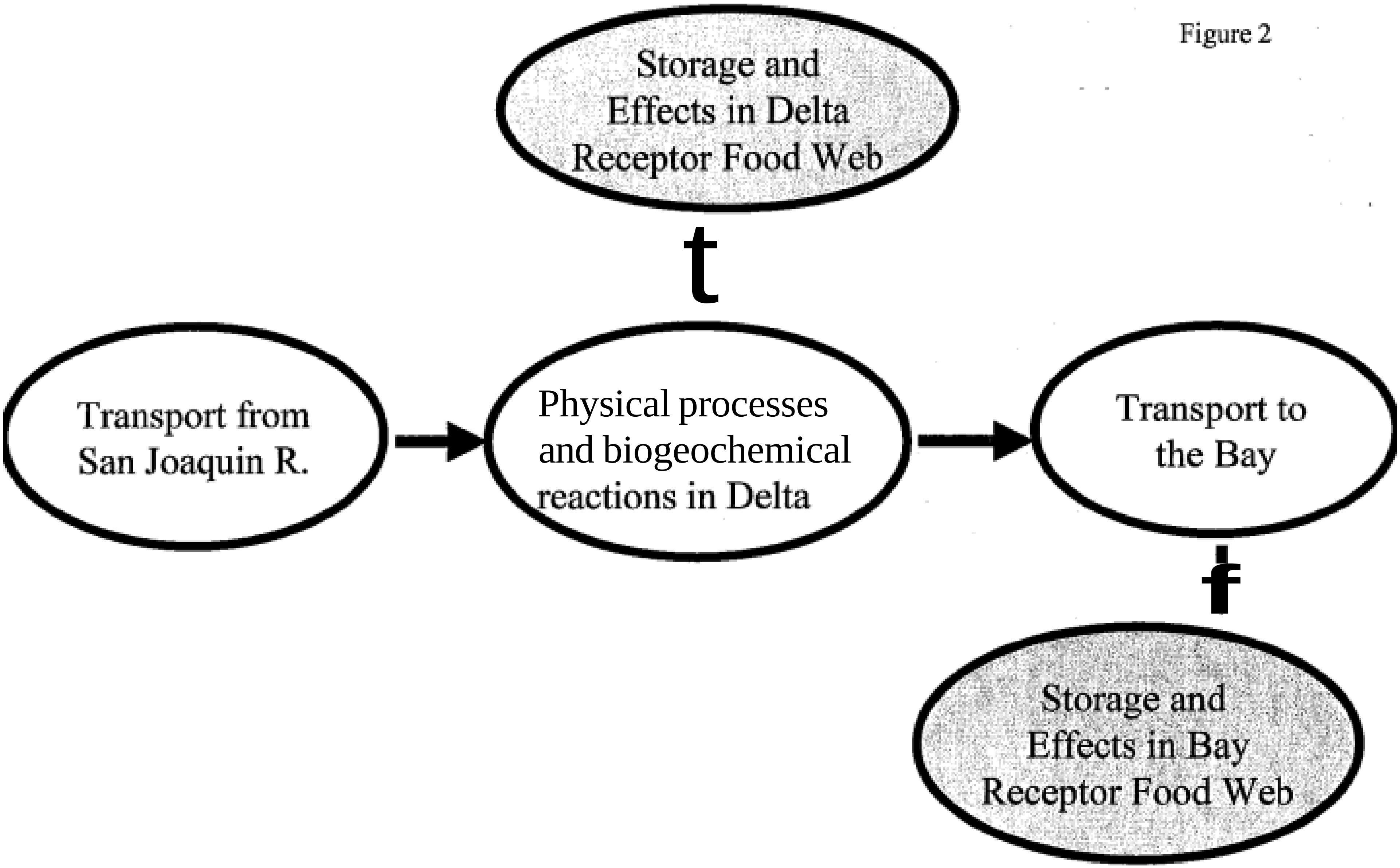

Delta
Bioaccumulation Model
Water Mgt.
Sacramento R.
Baseline
Selenate
Organic Selenide
San Joaquin R.
Enriched
Selenate
Organic Selenide
Water Mgt.
Forms of Se
Dissolved
[Se (VI)]
[Se(org)]
[Se (IV)]
Transformations
Primary Producers,
Detritus,
Bed Sediments
[Se (0)]
[Se(org)]
[Se (IV + VI)]
Residence Time
Consumer Species
Zooplankton
Amphipod
Chironomids
Bivalves
Trophic Transfer
Larval Striped Bass
Delta Smelt
Tule Perch
Splittail,
Inland Silversides
Sturgeon
Toxicity
Teratogenesis
Impaired
Reproductio[redacted]

Figure 2


Storage and
Effects in Delta
Receptor Food Web
Transport from
San Joaquin R.
Physical processes
and biogeochemical
reactions in Delta
Transport to
the Bay
Storage and
Effects in Bay
Receptor Food Web

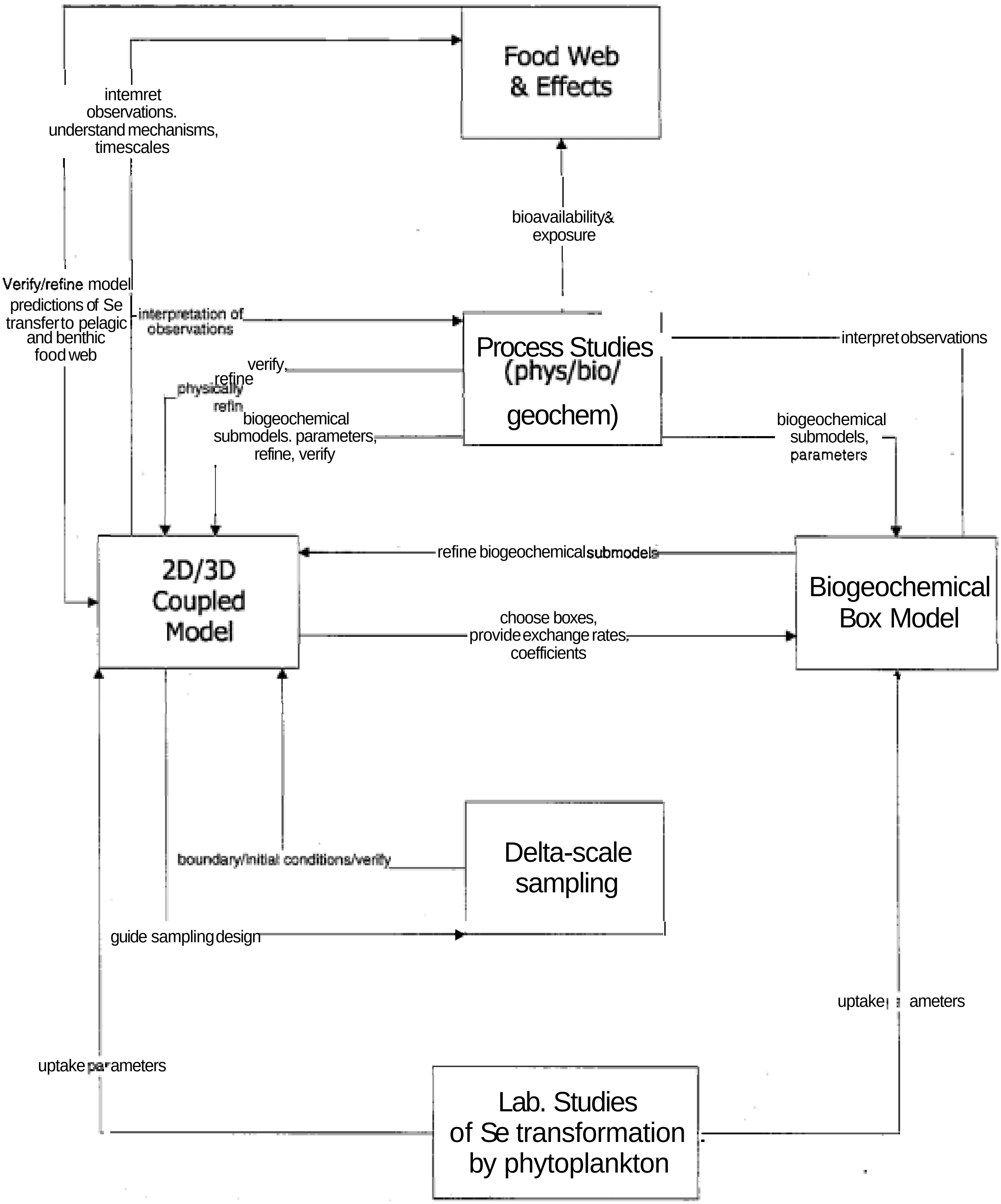

Food Web & Effects
intemret observations. understand mechanisms, timescales
bioavailability& exposure
Verify/refine model predictions of Se transfer to pelagic and benthic food web
interpretation of observations
Process Studies (phys/bio/ geochem)
interpret observations
verify, refine
physically refin
biogeochemical submodels. parameters, refine, verify
biogeochemical submodels, parameters
2D/3D Coupled Model
refine biogeochemical submodels
Biogeochemical Box Model
choose boxes, provide exchange rates, coefficients
Delta-scale sampling
boundary/initial conditions/verify
guide sampling design
uptake ameters
uptake parameters
Lab. Studies of Se transformation by phytoplankton

Figure 3

Figure **4**

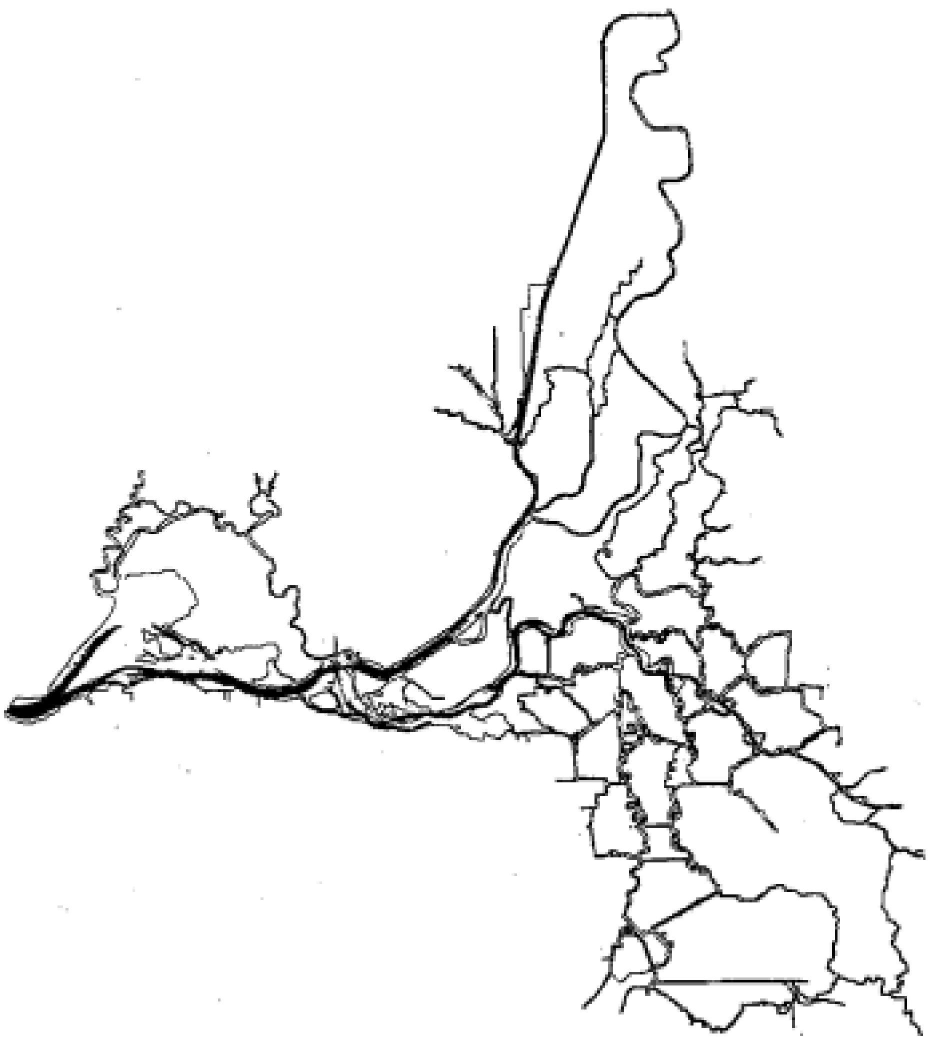


Figure 5

Physical-Biogeochemical Model

Hydrodynamics

- TRIM-based (Casulli 1990)
- 3D (multiple layers) or **2D** depth-averaged (1 layer)
- computationally efficient
- numerically stable
- wetting & drying **of** grid cells
- advective schemes for tracers (Burau et al. 1993; Gross et al. 1999a, b):
  - -mass conservative
  - -stable
  - -minimally diffusive
  - -accurate
- validated with field measurements

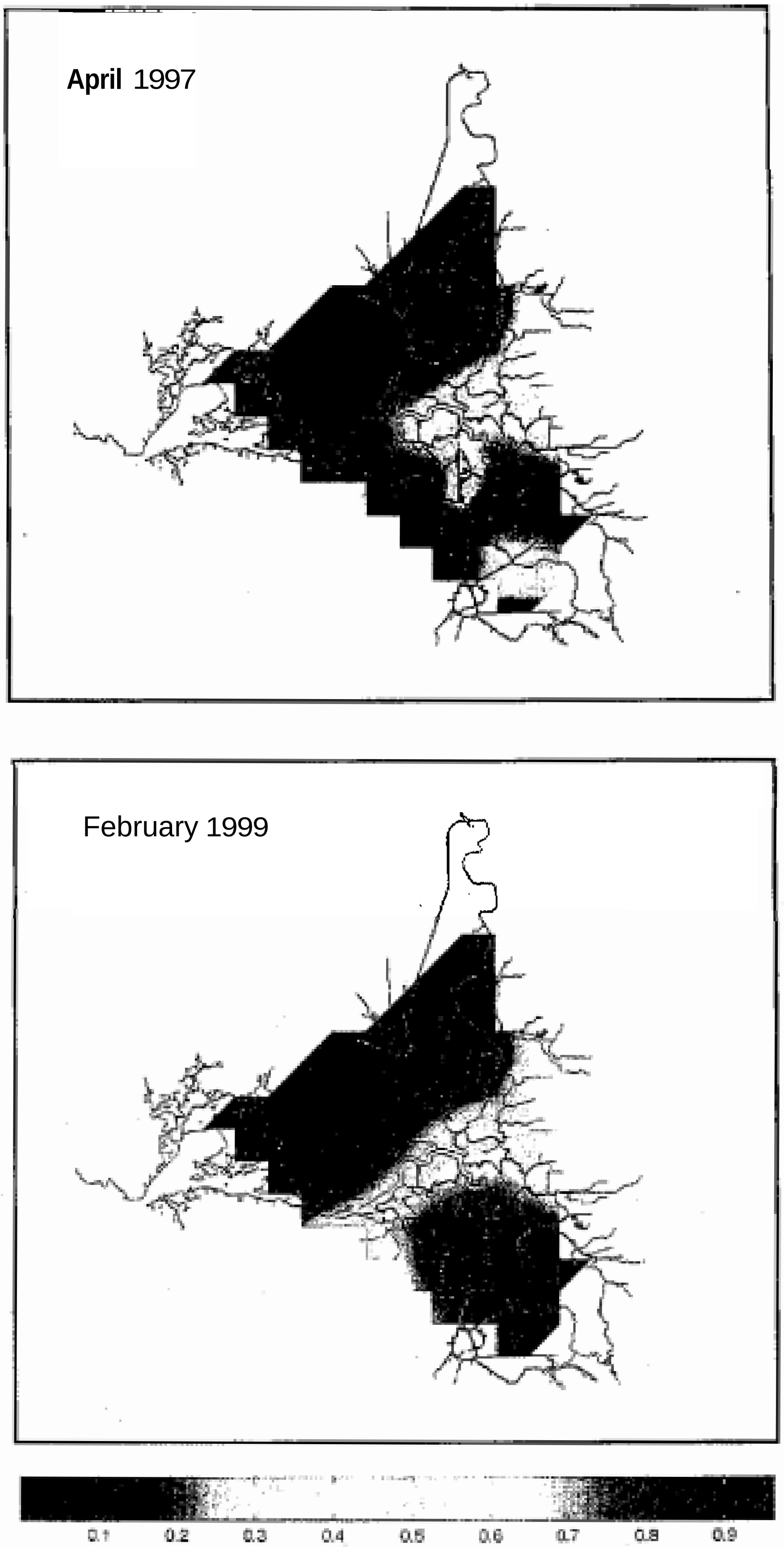
Phytoplankton dynamics.

- light- and temperature-driven photosynthesis and growth (Cloern et al. 1995)
- Delta-specific **P-I** parameters (Edmunds et al. 1999)
- light availability accounts for turbidity
- respiration **loss** (Cloern et al. 1995)
- benthic grazing rates calculated from measured benthic biomass and density of bivalves and Chironomid larvae, **if sufficiently** present; filtration rates based on published values
- zooplankton grazing based on counts **(DF&G, DWR)** converted to biomass, apply published functions for consumption rates as a function of temperature and phytoplankton biomass
- validate by field measurements of phytoplankton biomass

Dissolved Se reactions

- uptake by phytoplankton: Michaelis-Menten uptake model; maximum uptake rate & half-saturation constant based on laboratory experiments
- benthic fluxes based on measurements
- to approximate phytoplankton cellular Se content (particulate), employ simple empirical conversion from cellular C to cellular Se, accounting for ambient dissolved Se
- validate by field measurements of dissolved and particulate Se

Fraction of SJR Source after 30 Days



3D Evolution Equations for Phytoplankton Biomass "B" and Dissolved Selenium "S"

(solved in TRIM-based hydrodynamic/biogeochemical model)

$$\frac{\partial B}{at} = -\frac{\partial}{\partial x}(UB) - \frac{\partial}{\partial y}(VB) - \frac{\partial}{\partial z}(WB) + \frac{\partial}{\partial x}\left(K_x \frac{\partial B}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial B}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial B}{\partial z}\right) + \mu B - \frac{\partial}{\partial z}(\alpha B)$$

Time-dependence   *Advective transport*   *Diffusive/dispersive (mixing)*   *"Reactions"*

$$\frac{\partial S}{at} = -\frac{\partial}{\partial x}(US) - \frac{\partial}{\partial y}(VS) - \frac{\partial}{\partial z}(WS) + \frac{\partial}{\partial x}\left(K_x \frac{\partial S}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial S}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial S}{\partial z}\right) - (uptake) \pm (benthic\ flux)$$

Figure 7

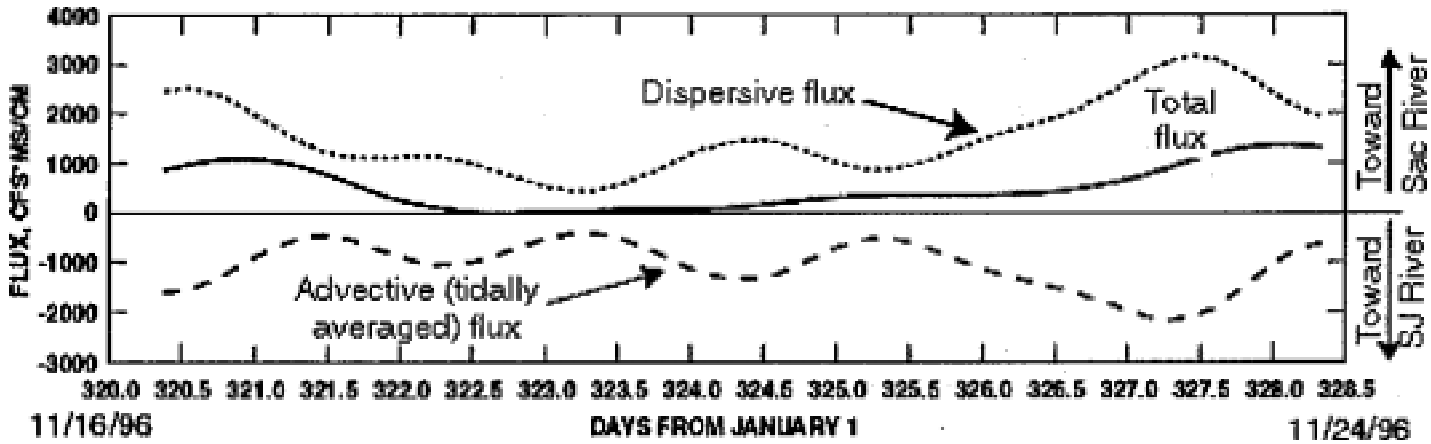
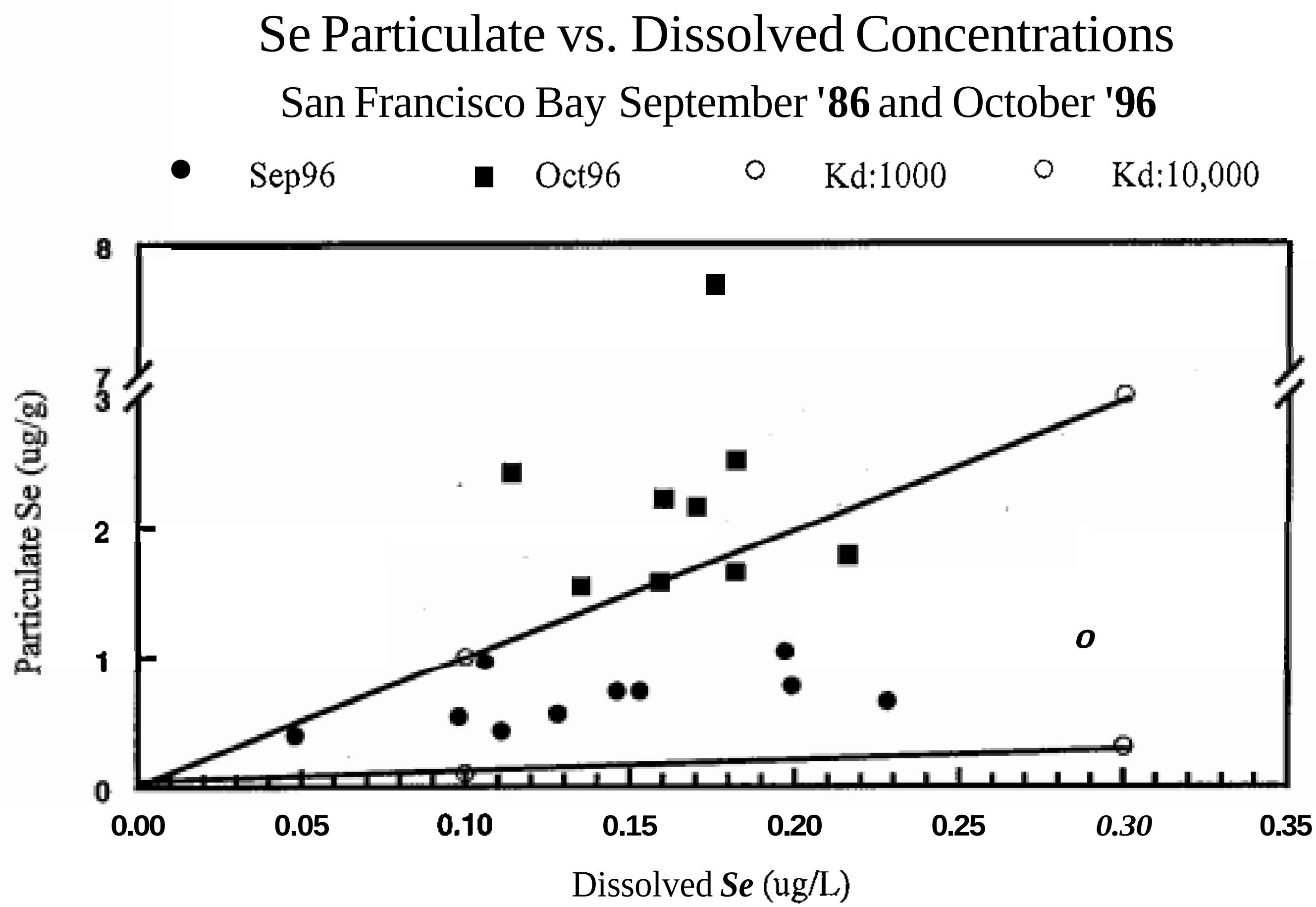


Figure 8. Measurements of conservative tracer flux through 3MS from 1996 by Eurau (pers. comm.). The conservative tracer is specific conductance. Total flux (solid line) of conductivity has two components: tidally-averaged "advective" flux (dashed line) and dispersive flux (dotted line). Tidally-averaged advective flux reflects the net flow of water mass; dispersive flux reflects the tidal-timescale processes (occurring over hours) which stretch and disperse a solute cloud. These 3MS data show that dispersive flux may **be** greater in magnitude than and in the opposite direction of net water flow and advective solute flux.

Figure 9



Se Particulate vs. Dissolved Concentrations
San Francisco Bay September '86 and October '96
Sep96
Oct96
Kd:1000
Kd:10,000
Particulate Se (ug/g)
8
7
3
2
1
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Dissolved Se (ug/L)

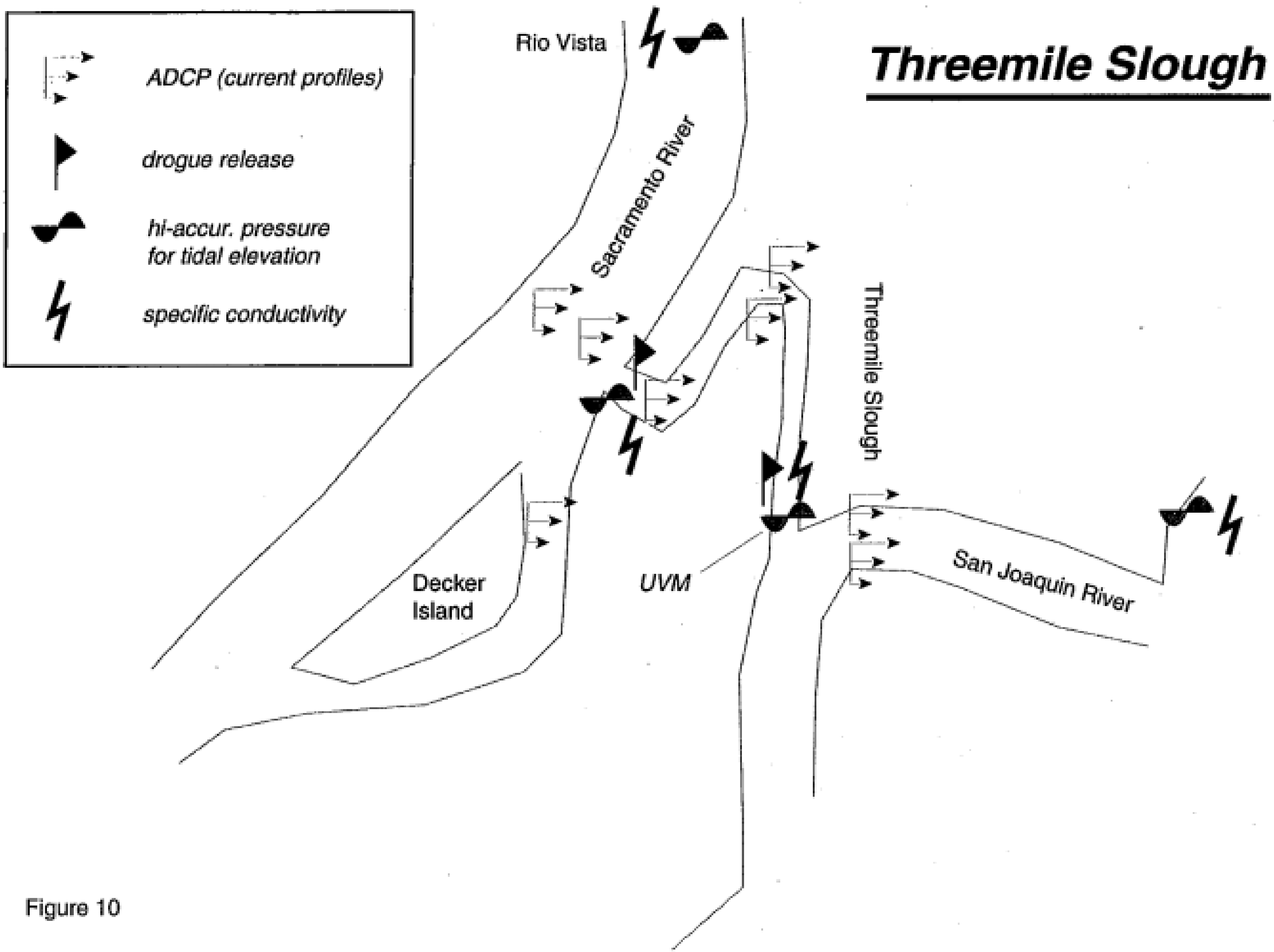

Threemile Slough
ADCP (current profiles)
drogue release
hi-accur. pressure
for tidal elevation
specific conductivity
Rio Vista
Sacramento River
Decker
Island
UVM
Threemile Slough
San Joaquin River

Figure 10

Mildred Island

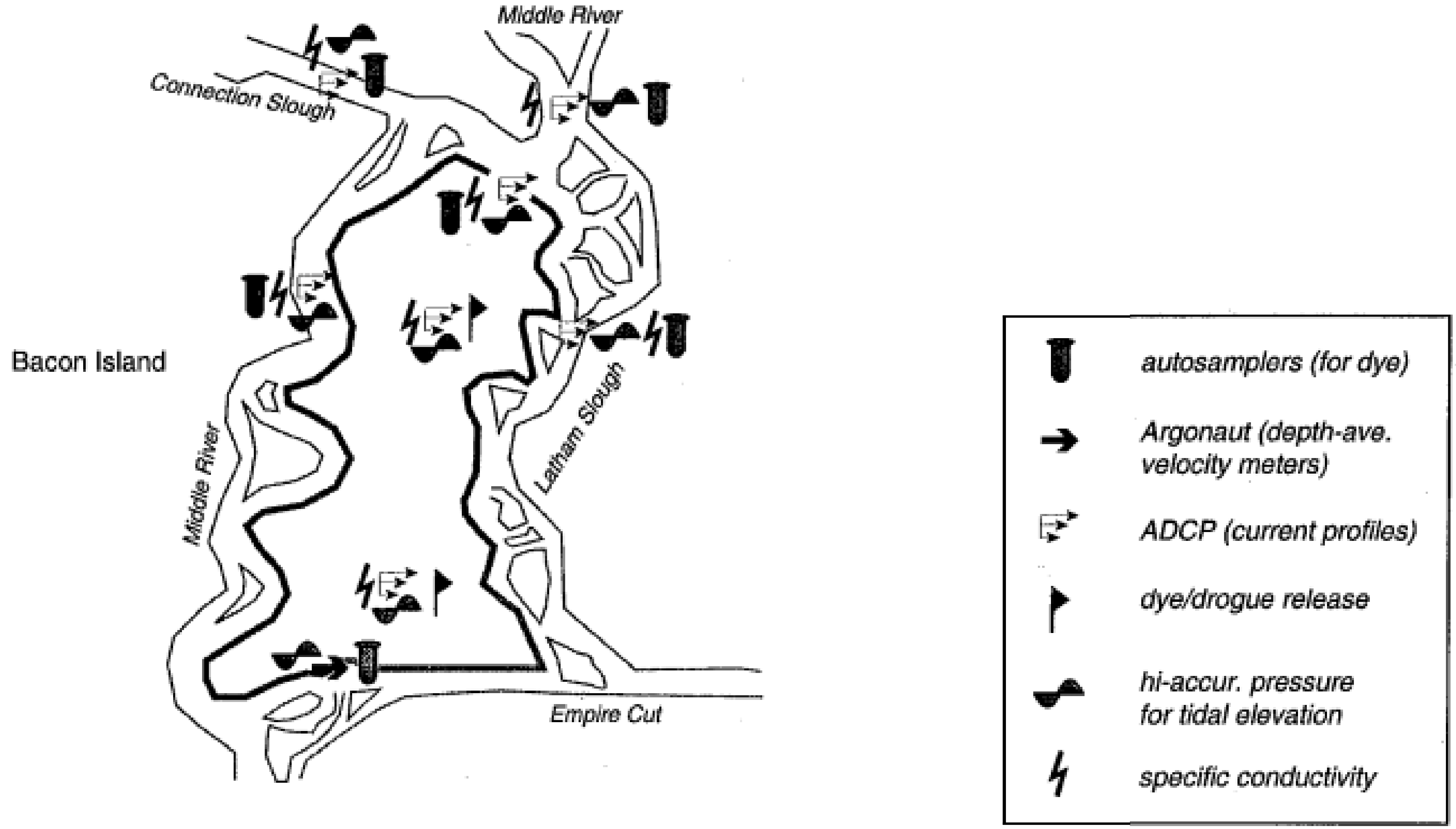


Figure 11

Franks Tract

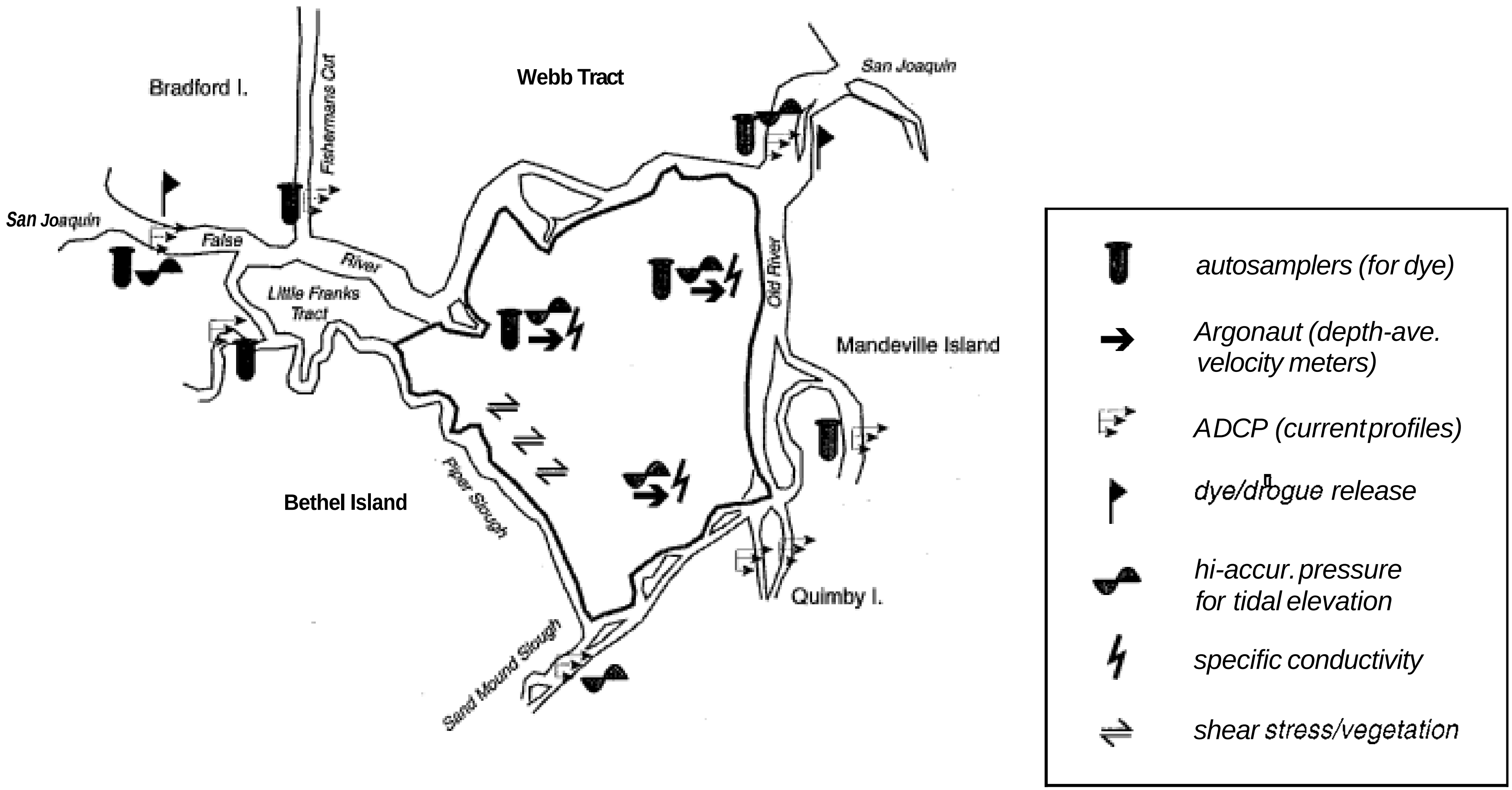


Figure 12

Chlorophyll distributions in Mildred Island
June 23, 1999

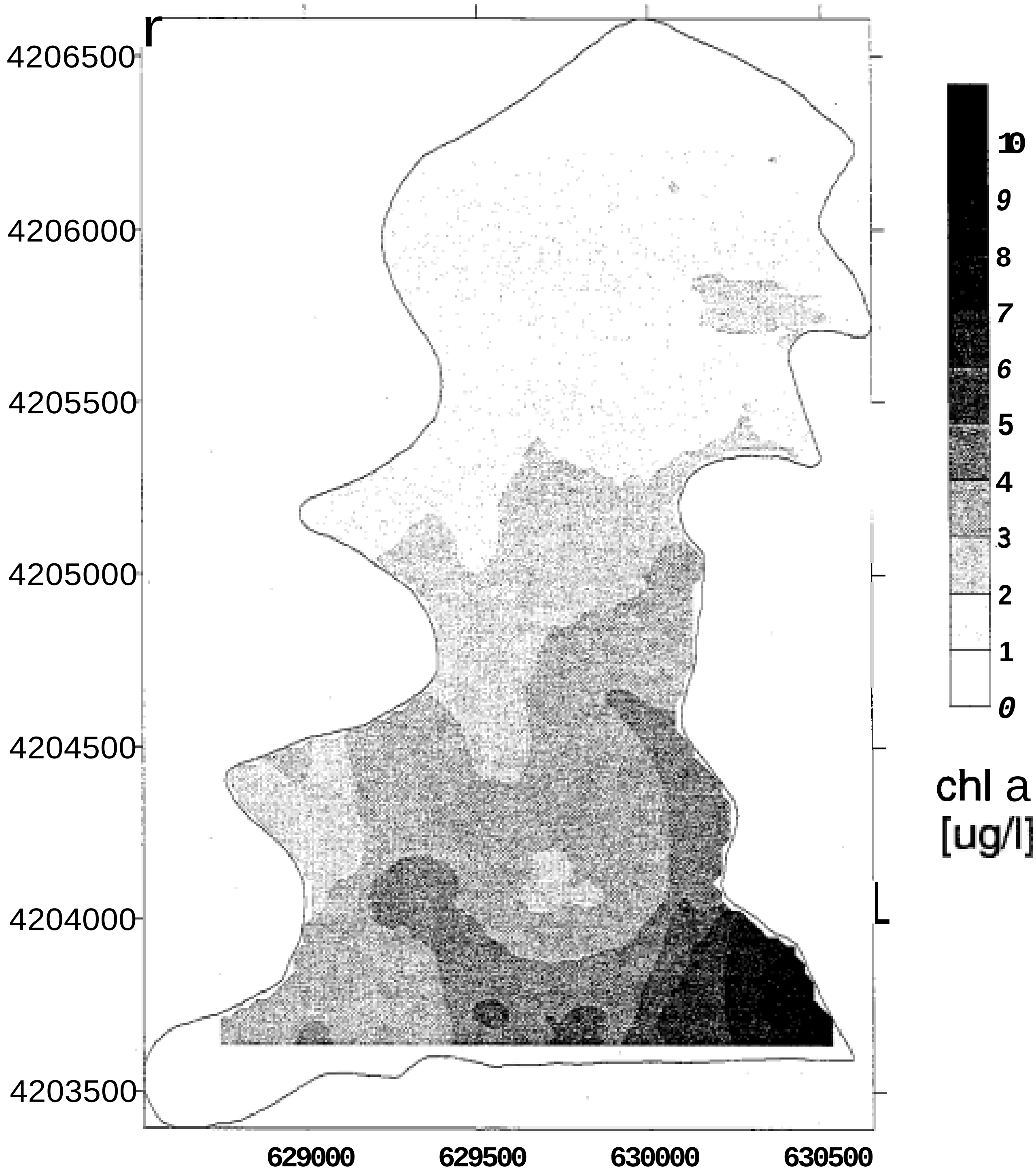


Figure 13

Mildred's Island

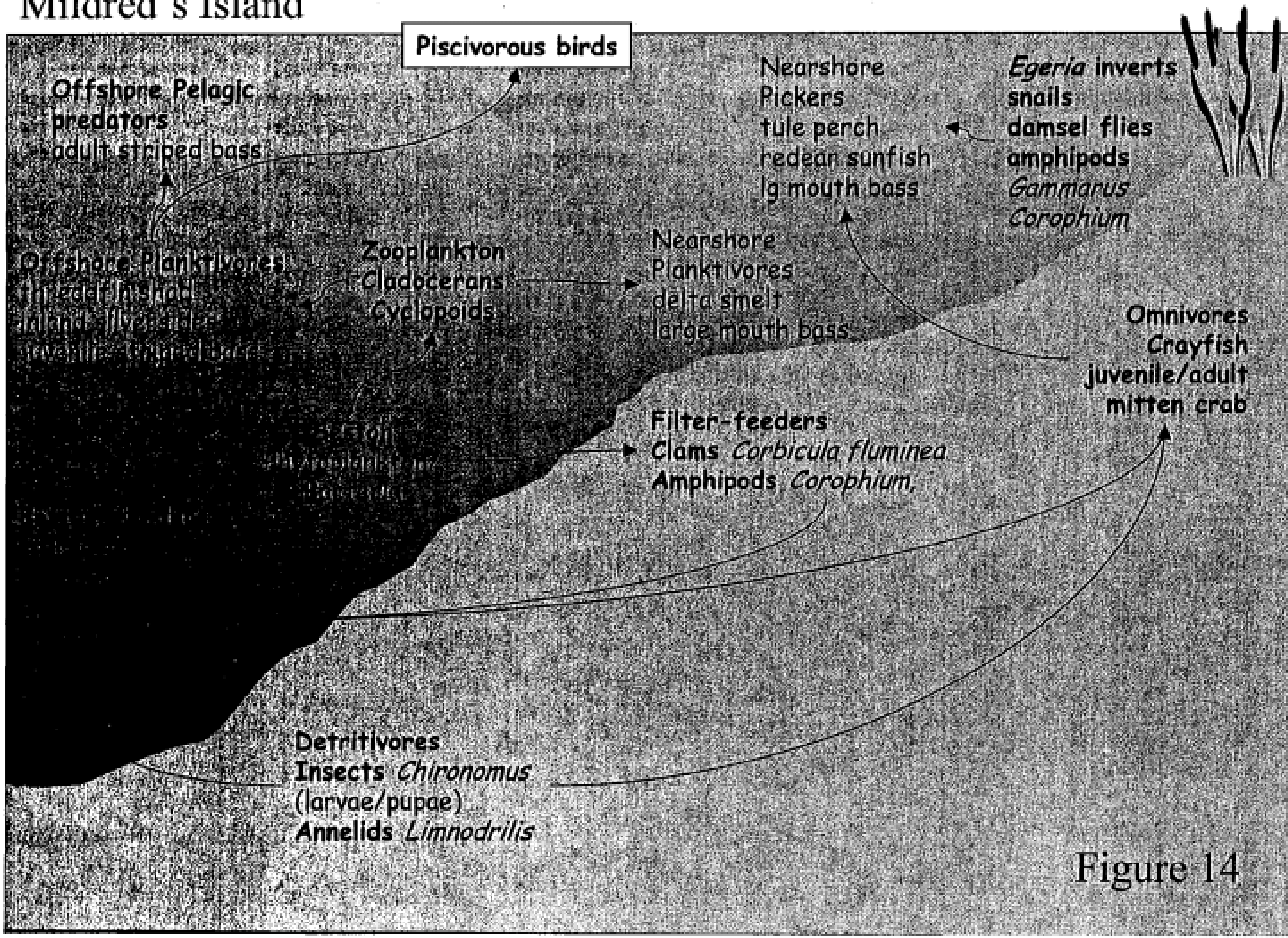
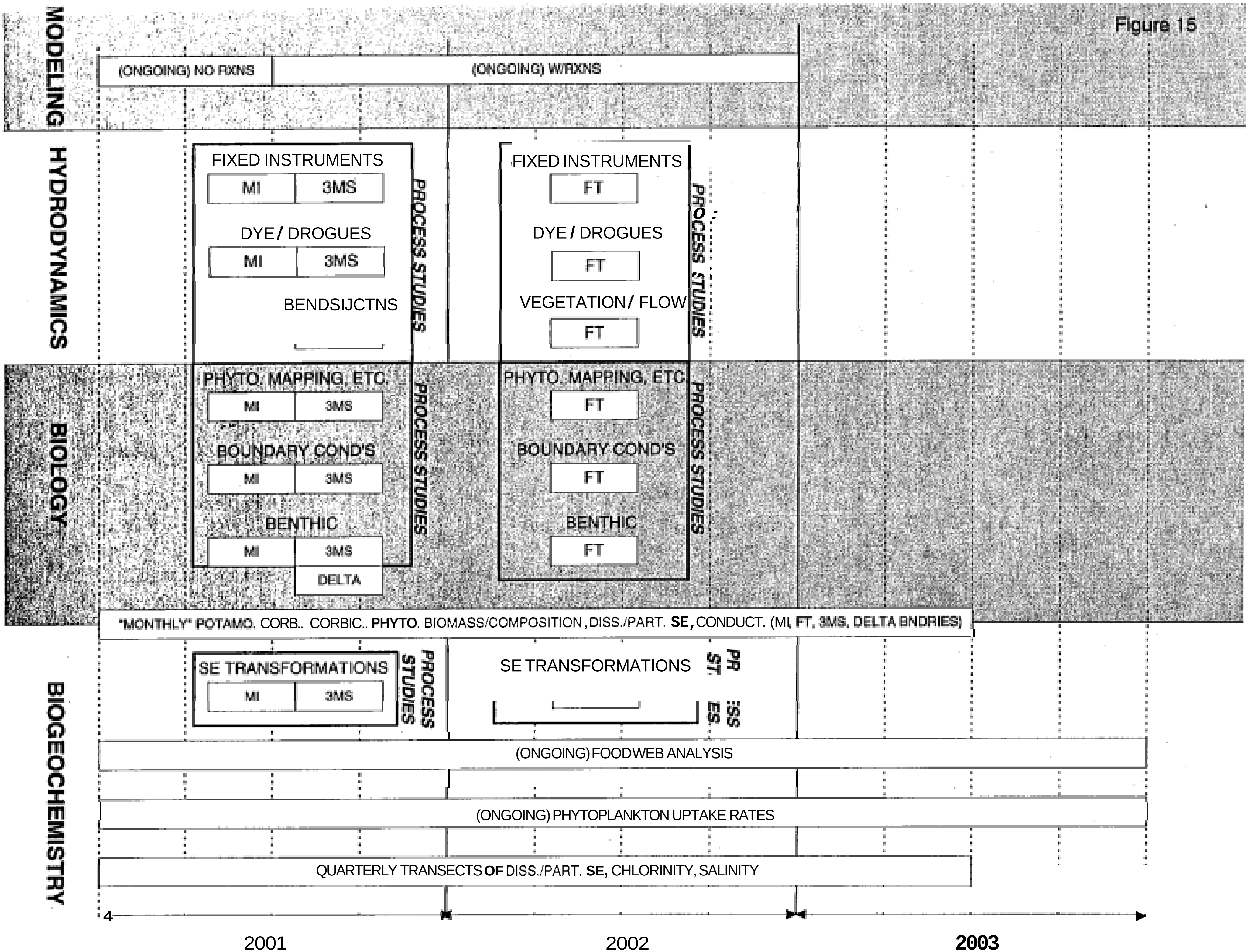


Figure 14


MODELING
(ONGOING) NO RXNS
(ONGOING) W/RXNS
HYDRODYNAMICS
FIXED INSTRUMENTS
MI
3MS
DYE / DROGUES
MI
3MS
BENDS/JCTNS
PROCESS STUDIES
FIXED INSTRUMENTS
FT
DYE / DROGUES
FT
VEGETATION / FLOW
FT
PROCESS STUDIES
BIOLOGY
PHYTO. MAPPING, ETC.
MI
3MS
BOUNDARY COND'S
MI
3MS
BENTHIC
MI
3MS
DELTA
PROCESS STUDIES
PHYTO. MAPPING, ETC.
FT
BOUNDARY COND'S
FT
BENTHIC
FT
PROCESS STUDIES
"MONTHLY" POTAMO. CORB.. CORBIC.. PHYTO. BIOMASS/COMPOSITION, DISS./PART. SE, CONDUCT. (MI, FT, 3MS, DELTA BNDRIES)
BIOGEOCHEMISTRY
SE TRANSFORMATIONS
MI
3MS
PROCESS STUDIES
SE TRANSFORMATIONS
PROCESS STUDIES
(ONGOING) FOODWEB ANALYSIS
(ONGOING) PHYTOPLANKTON UPTAKE RATES
QUARTERLY TRANSECTS OF DISS./PART. SE, CHLORINITY, SALINITY
2001
2002
2003
Figure 15

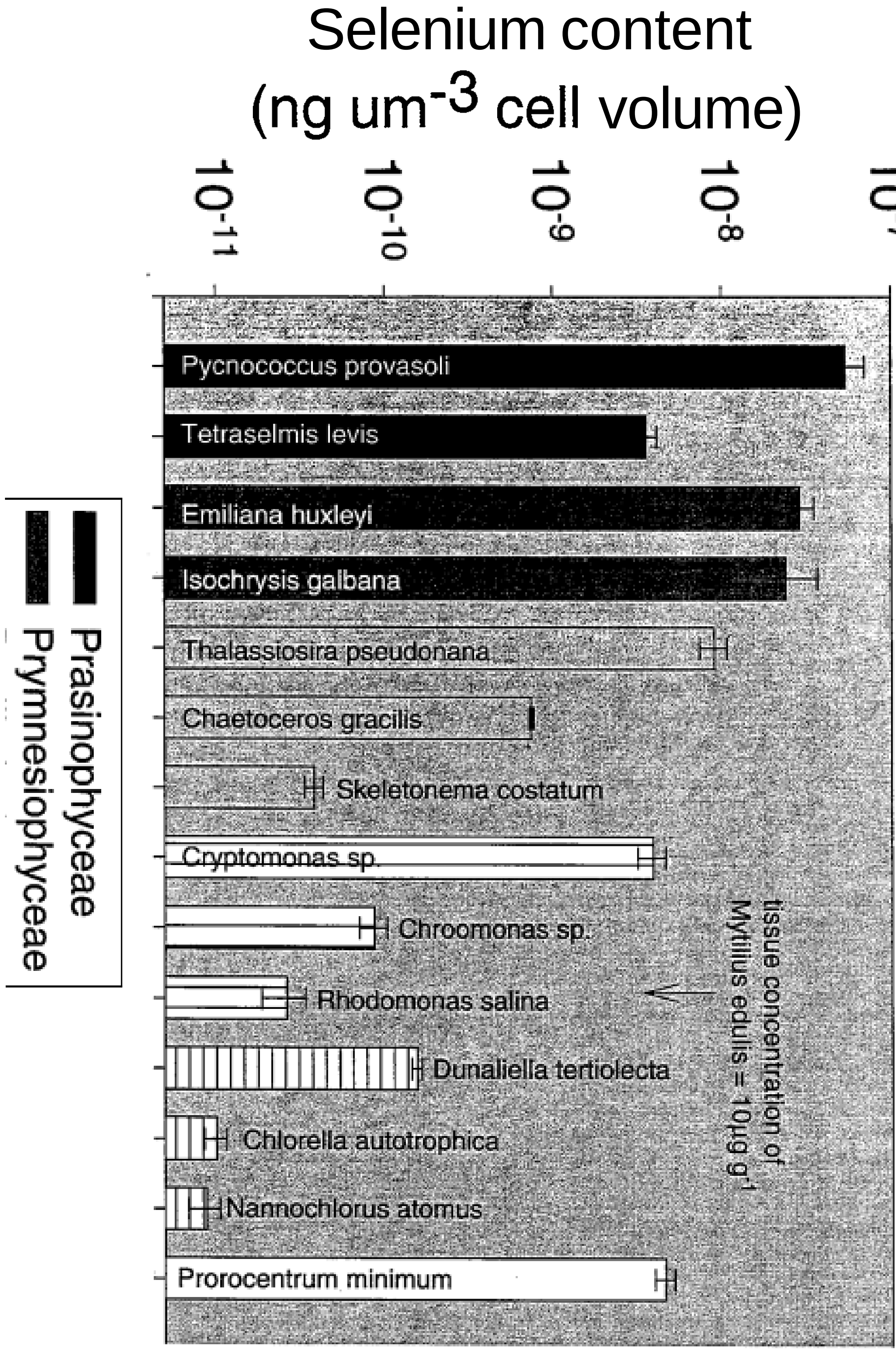

Selenium content
(ng um-3 cell volume)
10-11
10-10
10-9
10-8
10-7
Pycnococcus provasoli
Tetraselmis levis
Emiliana huxleyi
Isochrysis galbana
Thalassiosira pseudonana
Chaetoceros gracilis
Skeletonema costatum
Cryptomonas sp.
Chroomonas sp.
Rhodomonas salina
Dunaliella tertiolecta
Chlorella autotrophica
Nannochlorus atomus
Prorocentrum minimum
tissue concentration of
Mytilus edulis = 10μg g-1
Prasinophyceae
Prymnesiophyceae

Figure 16

Environmental Compliance Checklist

Not applicable

All applicants must fill out this Environmental Compliance Checklist. Applications must contain answers to the following questions to be responsive and to be considered for funding. ***Failure to answer these questions and 'include them with the application will result in the application being considered nonresponsive and not considered for funding.***

1. Do any of the actions included in the proposal require compliance with either the California Environmental Quality Act (CEQA), the National Environmental Policy ***Act*** (NEPA), **or** both?

   ____ **YES** ✓ **NO**

2. If **you** answered yes to # **1**, identify the lead governmental agency **for** CEQA/NEPA compliance

   ____
   Lead Agency

3. If **you** answered **no to** # 1, explain why CEQA/NEPA compliance is not required for the actions in the proposal.

   Research Only

4. If CEQA/NEPA compliance is required, describe how the project will comply with either **or** both of these laws. Describe where the project is in the compliance process and the expected date of completion.

5. Will the applicant require **access** across public **or** private property that the applicant does not **own to** accomplish the activities in the proposal?

   YES ✓ Bay Delta waterways only ~~NO~~

   If yes, the applicant must attach **written** permission for access from the relevant property owner(s). Failure to include **written** permission for access may result in disqualification of the proposal during the review process. Research and monitoring field projects for which specific field locations have not been identified **will** be required **to** provide **access** needs and permission for access with ***30*** days of notification of approval.

6. Please indicate what permits or other approvals may be required for the activities mntained in your proposal. Cheek all boxes that apply.

LOCAL

Conditional use permit	___	
Variance	___	
Subdivision Map Act approval	___	
Grading permit	___	
General plan amendment	___	
Specific plan approval	___	
Rezone		___
Williamson Act Contract cancellation	___	
Other ______________ (@leasespecify)		
None required	___	

STATE

CESA Compliance	___	(CDFG)
Streambed alteration permit	___	(CDFG)
CWA § 401 certification	___	(RWQCB)
Coastal development permit	___	(Coastal Commission/BCDC)
Reclamation Board approval	___	
Notification	___	(DPC, BCDC)
Other ______________ (@leasespecify)		
None required	___	

FEDERAL

ESA Consultation	___	(USFWS)
Rivers & Harbors Act permit	___	(ACOE)
CWA § 404 permit	___	(ACOE)
Other ______________ (please specify)		
None required	___	

DPC = Delta Protection Commission
CWA = Clean Water Act
CESA = California Endangered Species Act
USFWS = U.S. Fish and Wildlife Service
ACOE = U.S. Army Corps of Engineers

ESA = Endangered Species Act
CDFG = California Department of Fish and Game
RWQCB = Regional Water Quality Control Board
BCDC= Bay Conservation and Development Comm.

Land Use Checklist

All applicants must fill out this Land Use Checklist for their proposal. Applications must contain **answers** to the following questions to be responsive and to **be** considered for funding. ***Failure to answer these questions and include them with the application will result in the application being considered nonresponsive and not considered for funding.***

1. Do the actions in the proposal involve physical changes to the land (i.e. grading, planting vegetation, **or** breeching levees) **or** restrictions in land use (i.e. conservation easement **or** placement of land in a wildlife refuge)?

   ____ **YES** ✓ **NO**

2. **If NO to** # **1**, explain what type of actions are involved **in** the proposal (i.e., **research only,** planning only).

3. **If YES** to # **1**, what is the proposed land use change **or** restriction under the proposal?

4. **If YES** to # **1**, is the land currently under a Williamson **Act contract?**

   ____ **YES** ____ **NO**

5. **If YES** to # **1**, answer the following:

   Current land use ____
   Current zoning ____
   Current general plan designation ____

6. If **YES** to **#1**, is the land classified as Prime Farmland, Farmland of Statewide Importance **or** Unique Farmland **on** the Department of Conservation Important Farmland Maps?

   ____ **YES** ____ **NO** ____ **DON'T** KNOW

7. **If YES** to # **1**, how many acres of land will be subject to physical change **or** land use **restrictions** under the proposal? ____

8. **If YES to** # **1, is** the property currently being commercially farmed **or** grazed?

   ____ **YES** ____ **NO**

9. **If YES** to #8, what are the number of employees/acre ____
   the **total** number of employees ____

10. Will the applicant acquire any interest in land under the proposal (fee title or a conservation easement)?

______ **YES** ______ NO

11. What entity/organization will hold the interest? ____________________

12. If **YES** to # **10,** answer the following:

Total number of acres to be acquired under proposal ____________________
Number of awes to be acquired in fee ____________________
Number of awes to be subject to conservation easement ____________________

13. For all proposals involving physical changes to the land or restriction in land **use,** describe what entity or organization **will:**

manage the properly ____________________

provide operations and maintenance services ____________________

conduct monitoring ____________________

14. **For** land acquisitions (fee title or easements), will existing water rights also be acquired?

______ **YES** ______ **NO**

15. **Does** the applicant propose any modifications to the water right or change **in** the delivery of the water?

______ YES ______ NO

16. If **YES** to # **15,** describe ____________________